Operator's Manual
Evolution-15/30
High-Energy, High-Average Power,
Diode-Pumped, Kilohertz, Q-Switched,
Intra-Cavity Doubled, Nd:YLF Laser

COHERENT®
5100 Patrick Henry Drive
Santa Clara, CA.95054

Every effort has been made to ensure that the data given in this document is accurate. The information, figures, tables, specifications and schematics contained herein are subject to change without notice. Coherent makes no warranty or representation, either expressed or implied with respect to this document. In no event will Coherent be liable for any direct, indirect, special, incidental or consequential damages resulting from any defects in its documentation.

Technical Support

In the US:

Should you experience any difficulties with your laser or need any technical information, please visit our web site **www.Coherent.com**. Additional support can be obtained by contacting our Technical Support Hotline at 800-367-7890 (408-764-4557 outside the U.S.) or E-mail (clg.tech.services@Coherent.com). Telephone coverage is available Monday through Friday (except U.S. holidays and company shutdowns).

If you call outside our office hours, your call will be taken by our answering system and will be returned when the office reopens.

If there are technical difficulties with your laser that cannot be resolved by support mechanisms outlined above, please E-mail or telephone Coherent Technical Support with a description of the problem and the corrective steps attempted. When communicating with our Technical Support Department, via the web or telephone, the model and Laser Head serial number of your laser system will be required by the Support Engineer responding to your request.

Outside the U.S.:

If you are located outside the U.S. visit our web site for technical assistance or contact, by phone, our local Service Representative. Representative phone numbers and addresses can be found on the Coherent web site, **www.Coherent.com**.

Coherent provides telephone and web technical assistance as a service to its customers and assumes no liability thereby for any injury or damage that may occur contemporaneous with such services. These support services do not affect, under any circumstances, the terms of any warranty agreement between Coherent and the buyer. Operation of any Coherent laser with any of its interlocks defeated is always at the operator's own risk.

TABLE OF CONTENTS

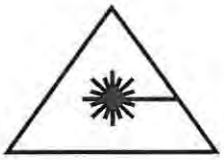
LIST OF FIGURES

LIST OF TABLES

Preface

This document contains user information for the Evolution-15/30 a High Energy, High Average Power, Diode-Pumped, kHz, Q-Switched, Intra-Cavity Doubled, Nd:YLF Laser.

Read this Operator Manual carefully before operating the laser for the first time. Special attention should be given to the material in Chapter Two: Laser Safety.



Use of controls or adjustments or performance of procedures other than those specified in this operator's manual may result in hazardous radiation exposure.

Use of the system in a manner other than that described herein may impair the protection provided by the system.

U.S. Export Control Laws Compliance

It is the policy of Coherent Inc., to comply strictly with U.S. export control laws.

Export and re-export of lasers manufactured by Coherent are subject to U.S. Export Administration Regulations, which are administered by the Commerce Department. In addition, shipments of certain components are regulated by the State Department under the International Traffic in Arms Regulations.

The applicable restrictions vary depending on the specific product involved and its destination. In some cases, U.S. law requires that U.S. Government approval be obtained prior to resale, export or re-export of certain articles. When there is uncertainty about the obligations imposed by U.S. law, clarification should be obtained from Coherent or an appropriate U.S. Government agency.

Symbols Used in this Document and on the System

This symbol is intended to alert the operator to the presence of dangerous voltages associated with the laser that may be of sufficient magnitude to constitute a risk of electric shock.

This symbol is intended to alert the operator to the presence of important operating and maintenance instructions.

This symbol is intended to alert the operator to the danger of exposure to hazardous visible and invisible laser radiation.

This symbol is intended to alert the operator to the danger of electro-static discharge (ESD) susceptibility.

CHAPTER ONE: DESCRIPTION AND SPECIFICATIONS

Introduction

The Evolution-15/30 is a diode-pumped, intra-cavity doubled, Q-switched Nd:YLF laser capable of producing average energy > 12 mJ (Evolution-15) and > 20 mJ (Evolution-30) at 527 nm at repetition rates above 1 kHz. The Evolution-15/30 represents a significant advance in this class of laser, offering the high efficiency, low maintenance, and excellent beam quality afforded by laser diode pumping.

The Evolution-15/30 laser system comprises four main elements:

- Optical laser bench assembly
- Power supply assembly
- Control computer
- Closed loop chiller

Shown with "Optional baseplate"

Figure 1-1. Evolution-15/30 System

Optical Laser Bench Assembly

The Evolution-15/30 optical laser bench is a sealed monolithic aluminum chassis, containing integrated opto-mechanical, electrical, and cooling assemblies, including:

- A diode-pumped, water-cooled, Nd:YLF laser head (pump chamber)
- An optical resonator
- Acousto-optical Q-switches
- A LBO frequency-doubling crystal in a temperature-controlled oven
- Safety shutter

The Evolution-15/30 is available in two variants—OEM and Scientific. In the Scientific version of the Evolution-15/30, the aluminum chassis described above is mounted on an aluminum base with an emission indicator, and four feet that allow adjustment of beam height. To minimize footprint and allow simple integration into other instruments, the OEM Evolution-15/30 is supplied without the aluminum base.

Power Supply Assembly

The power supply assembly includes a master control board and all the electronics to drive the laser diodes, stabilize the temperature of the LBO crystal, Q-switch the laser, and monitor interlocks. The power supply cabinet connects to the optical laser bench through a removable 3-meter umbilical cable. The power supply contains:

- Master control electronics
- Diode power supply
- LBO temperature controller
- Q-Switch driver
- Accessory electronics

Control Computer

The Evolution-15/30 comes with a commercial laptop computer and software to control and monitor the functions of the laser via an USB/RS-232 interface. Because of frequent changes in the availability of specific computer models, the particular computer delivered with each laser may vary in brand and features, but in general it will have a Pentium class processor $\geq$400 MHz, $\geq$32 MB of RAM, $\geq$2 GB hard drive, a CD-ROM drive, and a floppy drive. The control software for the Evolution-15/30 is pre-installed and tested with each laser, and is also delivered on CD-ROM.

Closed-Loop Chiller

A closed-loop chiller is included to dissipate the waste heat generated and maintain the wavelength of the laser diodes to ensure maximum absorption of the pump light in the gain medium. The chiller has two hoses with quick-release connectors, a water filter, and an internal pressure regulator valve to reduce the water pressure at the laser bench. A chemical additive is included to prevent algae growth and corrosion in the water system.

Specifications

Table 1-1. Specifications

PERFORMANCE*	1 KHZ	5 KHZ
Average Power [W]	> 12/20 W	> 15/30 W
Energy per Pulse [mJ]	> 12/20 mJ	> 3/6 mJ
Wavelength	527 nm	
Beam Diameter (nominal at output)	5 mm	
Energy Stability (RMS)	< 1%	
Beam Profile	Multi-mode, quasi flat-top	
Polarization	Linear, horizontal	
* Specifications subject to change without notice. Specifications on purchase order supersede all other published specifications.		

Dimensions

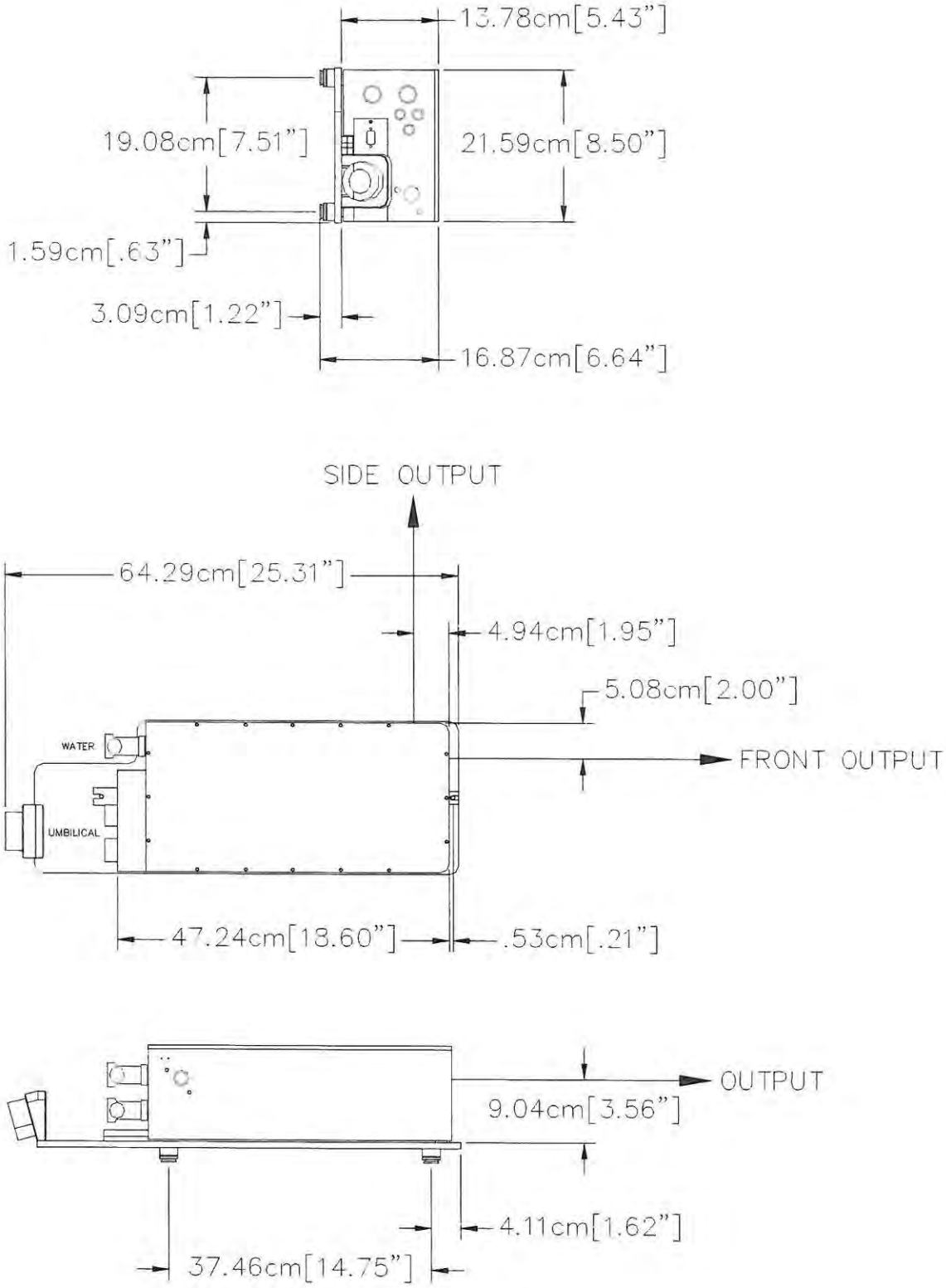


Figure 1-2. Laser Bench Dimensions

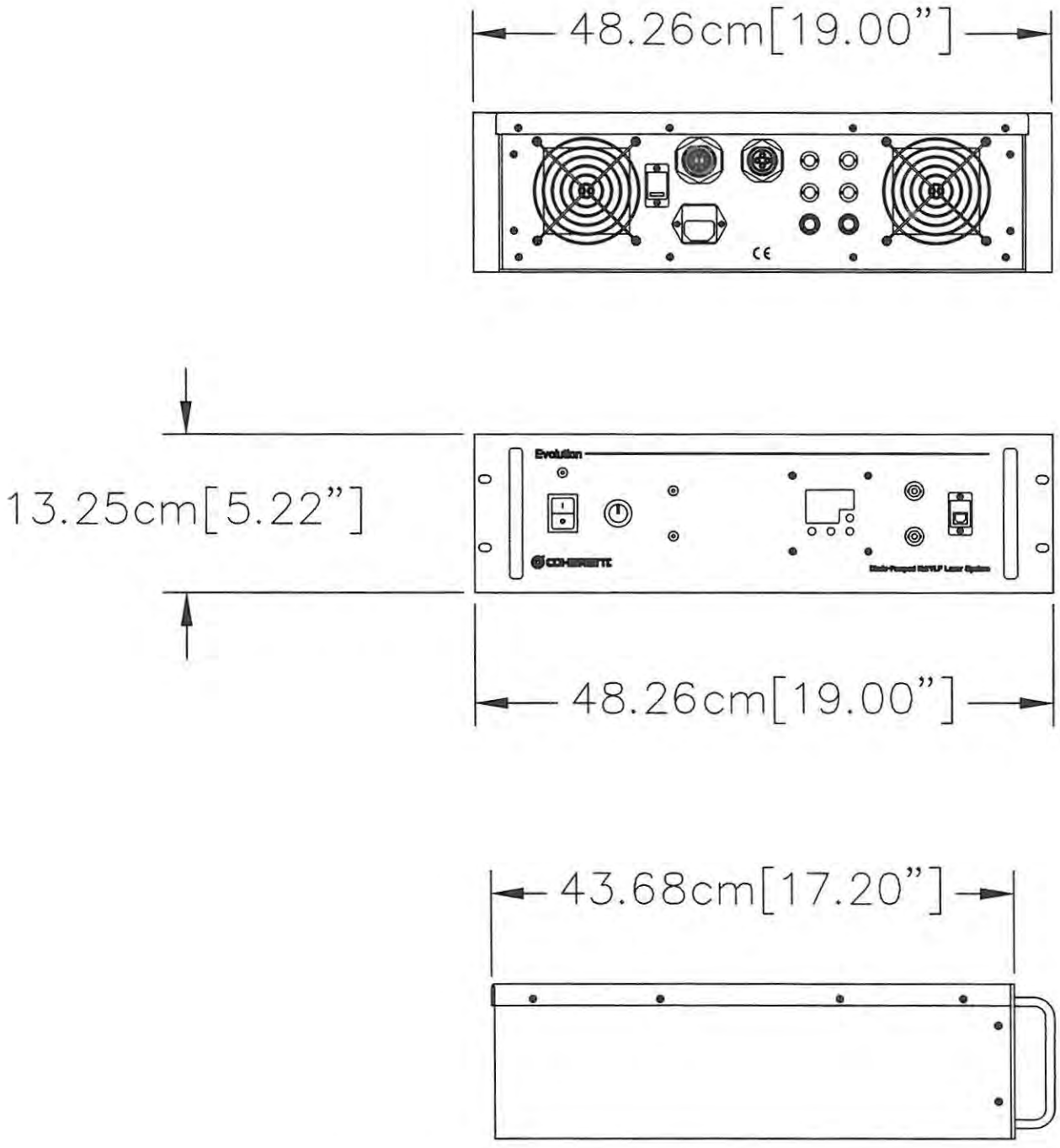
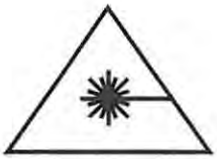


Figure 1-3. Power Supply Dimensions

CHAPTER TWO: LASER SAFETY

This user information is in compliance with section 1040.10 of the CDRH Performance Standards for Laser Products from the Health and Safety Act of 1968. Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.



The Evolution-15/30 is a Class IV-High Power Laser whose beam is a safety and fire hazard. Take precautions to prevent exposure to direct or reflected beams. Diffuse as well as specular reflections can cause severe eye or skin damage.

This safety chapter should be thoroughly reviewed prior to operating the Evolution-15/30 system described in this manual. Safety instructions presented throughout this manual must be followed carefully.

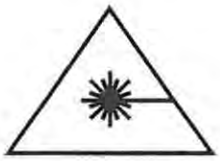
Hazards

Hazards associated with lasers generally fall into the following categories:

- Exposure to laser radiation that may result in damage to the eyes or skin.
- Exposure to chemical hazards such as particulate matter or gaseous substances released as a result of laser material processing or a by-product of the lasing process itself.
- Electrical hazards generated in the laser power supply or associated circuits.
- Secondary hazards such as:
  - X-radiation from faulty power supplies
  - Pressurized lamps, hoses, cylinders, etc.
  - Pressurized liquids and gasses

Optical Safety Precautions

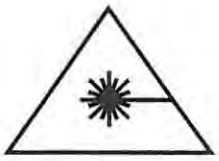
Because of its special properties, laser light poses safety hazards not associated with light from conventional sources. The safe use of lasers requires that all laser users—and everyone else near the laser system—are aware of the dangers involved. The safe use of the laser depends upon the user becoming familiar with the instrument and the properties of intense and coherent beams of light.



Direct eye contact with the output beam from the laser will cause serious damage and possible blindness.

Laser beams can ignite volatile substances such as alcohol, gasoline, ether and other solvents, and can damage light-sensitive elements in video cameras, photomultipliers and photodiodes. Reflected beams may also cause damage. For these reasons, the user is advised to follow the precautions below.

1. Observe all safety precautions in the operator's manual.
2. Exercise extreme caution when using solvents in the area of the laser.
3. Limit access to the laser to qualified users who are familiar with laser safety practices and who are aware of the dangers involved.
4. Never look directly into the laser light source or at scattered laser light from any reflective surface. Never sight down the beam into the source.
5. Maintain experimental setups at low heights to prevent inadvertent beam-eye encounter at eye level.

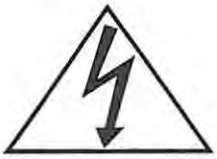


Laser safety glasses can present a hazard as well as a benefit while they protect the eye from potentially damaging exposure; they block light at the laser wavelengths that prevents the operator from seeing the beam. Therefore, use extreme caution even when using safety glasses.

6. As a precaution against accidental exposure to the output beam or its reflection, those using the system should wear laser safety glasses as required by the wavelength being generated.
7. Avoid direct exposure to the laser light. The intensity of the beam can easily cause flesh burns or ignite clothing.

8. Use the laser in an enclosed room. Laser light will remain collimated over long distances and therefore presents a potential hazard if not confined.
9. Post warning signs in the area of the laser beam to alert those present.
10. Advise all those using the laser of these precautions. It is good practice to operate the laser in a room with controlled and restricted access.

Electrical Safety Precautions



Normal operation of the Evolution-15/30 should not require access to the power supply circuitry. Removing the power supply cover will expose the user to potentially lethal electrical hazards. Contact an authorized service representative before attempting to correct any problem with the power supply.

The following precautions must be observed by anyone when working with potentially hazardous electrical circuitry:

- Disconnect main power lines before working on any electrical equipment when it is not necessary for the equipment to be operating.
- Do not short or ground the power supply output. Protection against possible hazards requires proper connection of the ground terminal on the power cable, and an adequate external ground. Check these connections at the time of installation, and periodically thereafter.
- Never work on electrical equipment unless there is another person nearby who is familiar with the operation and hazards of the equipment, and who is competent to administer first aid.
- When possible, keep one hand away from the equipment to reduce the danger of current flowing through the body if a live circuit is touched accidentally.
- Always use approved, insulated tools when working on equipment.
- Special measurement techniques are required for this system. A technician with a complete understanding of the system

operation and associated electronics must select ground references.

Protective Eye Wear

It is recommended that laser-safe eyewear protecting across at least the following wavelength ranges be worn at all times when the Evolution-15/30 is operating:

- 1047 to 1053 nm – covers the fundamental wavelength at which the Evolution-15/30 operates
- 523 to 527 nm – covers the second harmonic wavelength output of the Evolution-15/30
- 794 to 810 nm – covers the wavelength emitted by the laser diodes

During normal operation of the laser, the operator must not be exposed directly to hazardous diode laser emission. Removal of the mechanical housing cover, however, will not only invalidate the user's warranty, but will also expose the laser operator to hazardous diode laser radiation.

CDRH Compliance

The safety features listed below have been incorporated into the Scientific version of the Evolution-15/30 to conform to Federal performance standards, as required by 21 CFR 1040.10(h)(1)(iv). Any modification or use of the Evolution-15/30 that changes, disables, or overrides the function of the engineering controls and safety features invalidates the Class IV certification of the laser described in this manual.

Keyswitch

A separate keyswitch is provided to enable power to the laser. The key cannot be removed from the switch except in the OFF position. This assures that use of the laser by unauthorized or unqualified personnel can be prevented.

Warning Labels

Certification and warning labels are affixed to the Evolution-15/30 to verify compliance with 21 CFR 1040, to provide information on the wavelength and power emitted, and to warn the user against accidental exposure to laser radiation. The location and type of warning logotype labels used on the Evolution-15/30 laser bench for both the Scientific and OEM versions, as well as the laser power supply, are shown in Figure 2-1, Figure 2-2 and Figure 2-3 respectively.

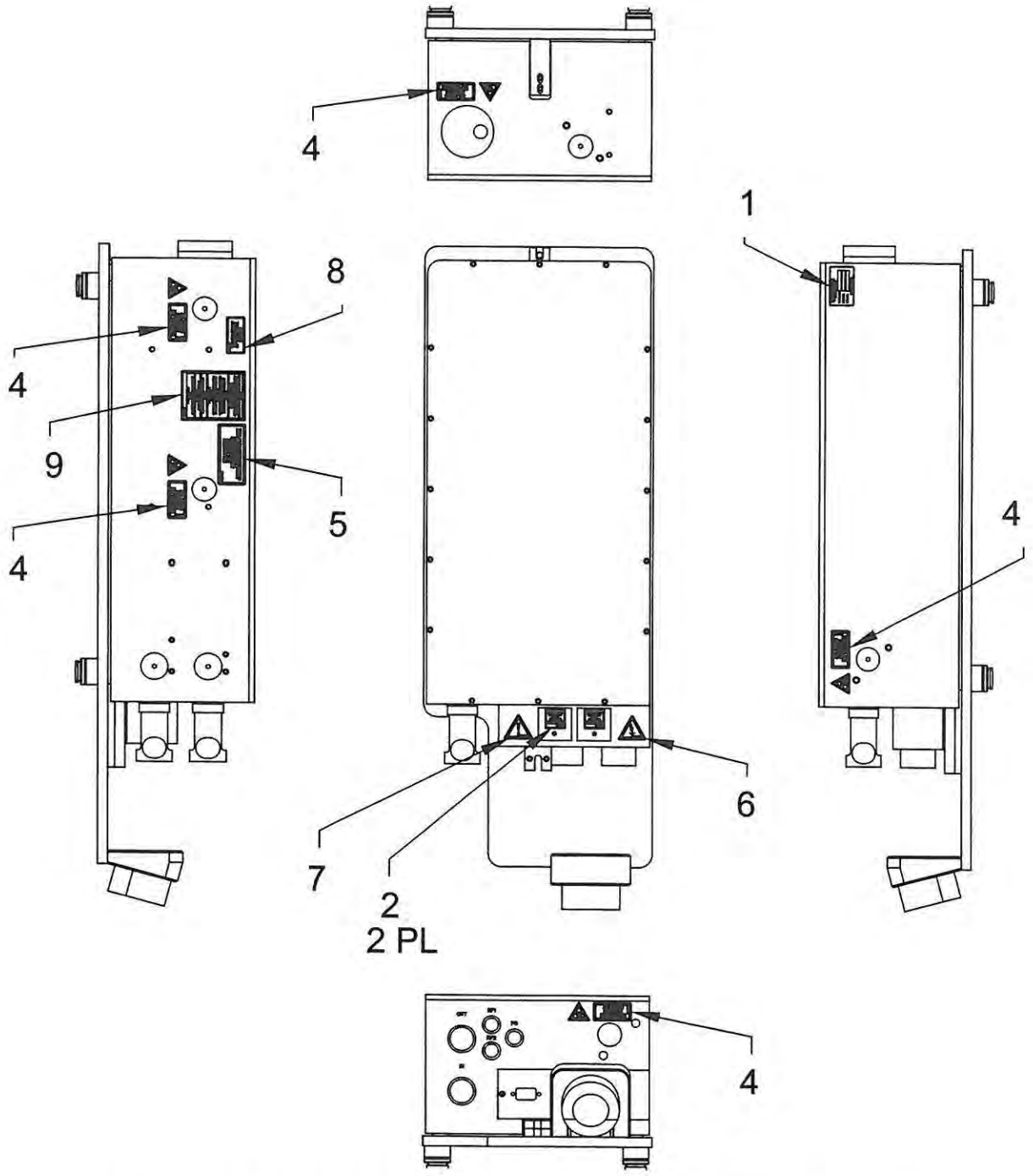


Figure 2-1. CDRH/CE Radiation Control Drawing, Scientific Version

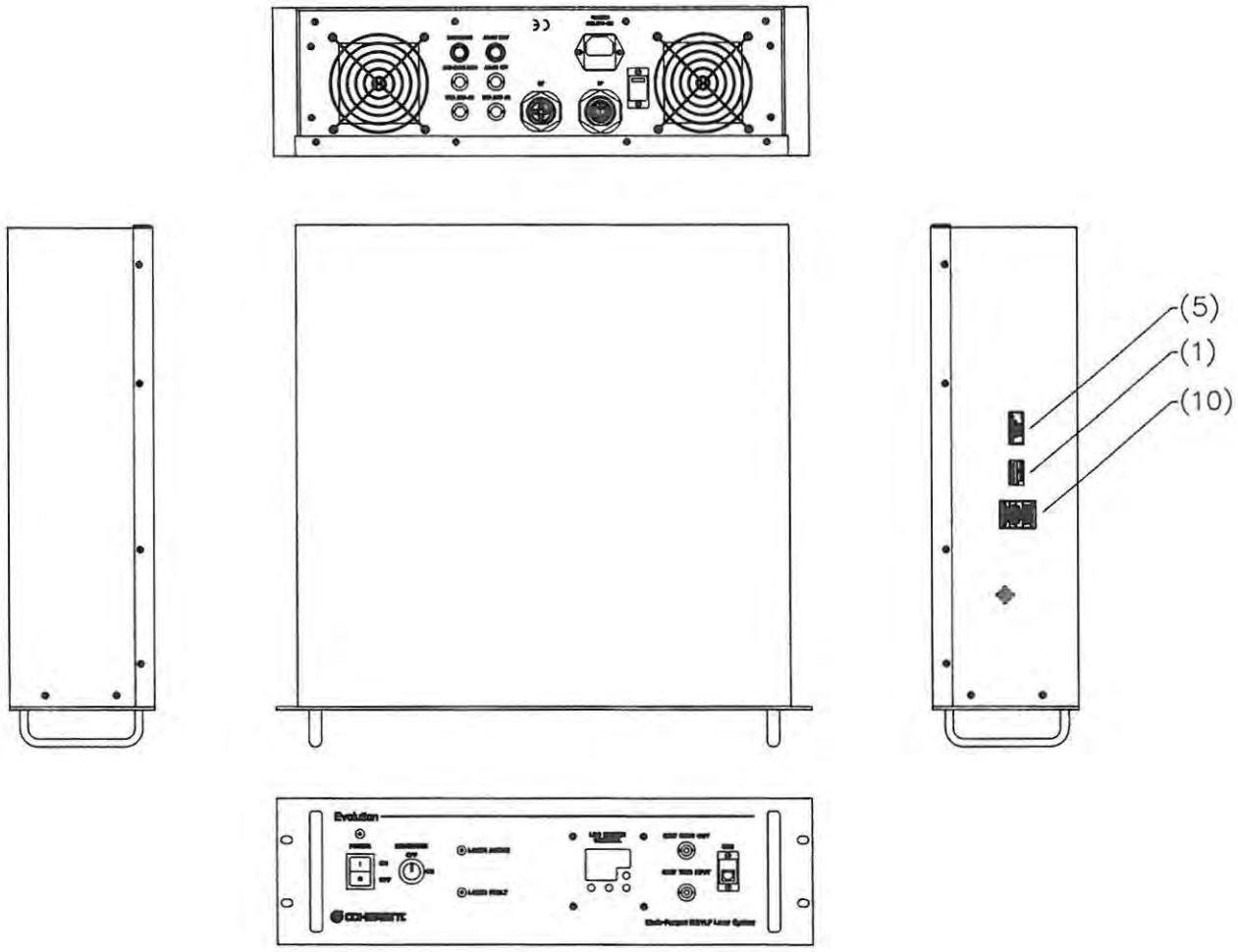
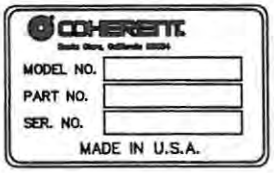


Figure 2-2. Power Supply Cabinet CDRH/CE Radiation Control Drawing

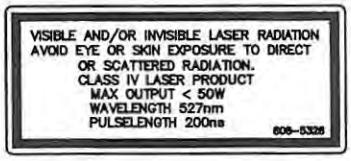


IDENTIFICATION/CERTIFICATION LABEL (1)

DANGER LASER BEAM LABEL, HEAD (2)

INTERLOCKED COVER LABEL, HEAD (3)

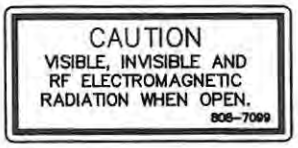
APERTURE LABEL, HEAD (4)



DANGER LABEL, HEAD–EVOLUTION (5)

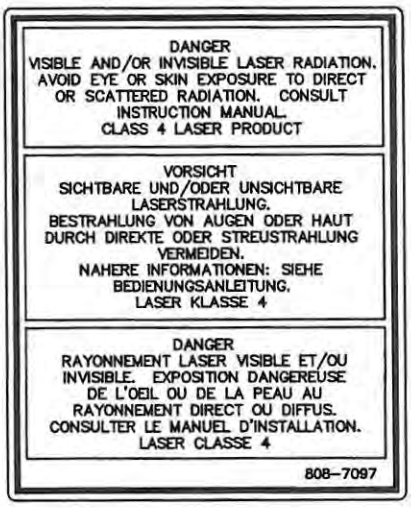
CAUTION LABEL (6)

CAUTION LABEL (7)



RF CAUTION LABEL (8)

CE WARNING LABEL, INTERLOCK DEFEATED (9)



CE WARNING LABEL, POWER SUPPLY (10)

Figure 2-3. CDRH/CE Radiation Control Drawing Labels

For safety, translations of the warning labels are provided in for non-English speaking operators. The number in parentheses in the first column corresponds to the label number listed on the previous page.

Table 2-1. Label Translations

LABEL #	FRENCH	GERMAN	SPANISH	DUTCH
Danger Label (5) Inter-locked Cover Label (3)	Danger! Rayonne-ment Laser Visible et/ou Invisible en Cas D'Ouverture et lorsque la securité est neutral-isée; exposition dangereuse de l'oeil ou de la peau au rayonne-ment direct ou diffus. Laser de Classe 4.	Vorsicht! Sichtbare und/oder unsichtbare Laserstrahlung wenn geöffnet und Sicher-heits-verriegelung überbruckt. Bestrahlung von Augen oder Haut durch direkt oder Streustrahlung vermeiden. Laser Klasse 4.	Peligro! Al abrir y retirar el dispositivo de seguridad exist radia-cion laser visible y invisible; evite que los ojos o la piel queden expuestos tanto a la radiacion directa como a la dispersa. Producto laser clase 4.	Gevaar! Zichtbare en onzichtbare lasers-traling! Vermijd bloot-stelling van oog of huid ann direkte straling of terug-kaatsingen daarvan! Klas 4 laser produkt.
Aperture Label (4)	Exposition Dangereuse! Rayonne-ment visible et/ou invisible est emis par cette ouverture	Austritt von sichtbarer und unsichtbarer Laserstrahlung. Bestrahlung vermeiden!	Por esta abertura se emite radiacion laser visible e invisible; evite la exposicion	Vanuit dit apertuur wordt zichtbare en onzichtbare lasers-traling geemiteerd! Vermijd blootstelling!

Remote Interlock Connector

There are two interlock connectors, one interlock for the door and an "Aux Interlock" for the power supply software to accept a command from the Evolution computer software to set CW mode (RF off).

The remote interlock connector at the back of the power supply cabinet (marked INTERLOCK) must be used to connect an external CDRH interlock (such as a switch on the door to the laser room). The interlock circuit will then terminate laser action automatically if the door is opened to the laser operating area. To connect the inter-lock switch, remove the supplied external jumper plug, and either re-wire according to the wiring diagram in Figure 2-4, or use a similar connector. Wire the external interlock switch normally closed, such that if the door or safety device and the switch opens, the power supply will immediately turn the laser diodes off. This is a safety precaution to prevent any unaware personnel from inad-vertent exposure to laser radiation.

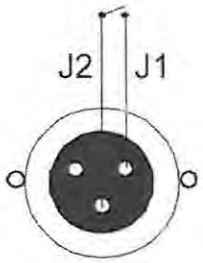


Figure 2-4. External Interlock Connector (Evolution Power Supply)

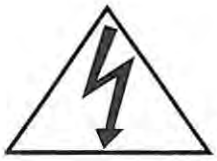
The interlock function causes the diodes to switch off when the interlock contacts are opened. Lasing can only be resumed by closing the external interlock circuit contacts and cycling the keyswitch to clear the interlock function. The laser must not be operated unless the remote interlock function is in use.

Protective Housings

The laser beam path is contained within the mechanical housing of the laser bench until it exits at the front (or side) output port. The diode-pumped head is also contained within this housing to shield the user from stray laser diode light and to protect the laser diodes from exposure to dust and electrostatic discharge.

Cover Safety Interlocks

Interlock micro-switches are used to ensure that the Evolution-15/30 cannot be operated if the machined metal cover protecting the optical cavity is not in place.



Do not operate the Evolution-15/30 with any covers removed, except when absolutely necessary while performing required service. Operation without the covers may expose users to hazardous voltages and laser radiation, and also increases the rate of optical surface contamination. Unauthorized removal of the cover protecting the optical cavity will void the warranty.

Emission Indicators

After issuing a START command, an emission indicator lights at the laser bench to warn that the laser is about to emit laser radiation.

Scientific Evolution-15/30

An indicator light on the front of the laser housing lights any time current is supplied to the laser diodes. This warns the user that hazardous laser radiation is present or can be accessed.

Note: When the emission indicator is illuminated, diode laser light is present inside the housing, even though the laser cavity may not be emitting green or infrared laser radiation. (This situation may occur if the laser is in Hold-Off mode, for example.)

OEM Evolution-15/30

A detachable emission indicator is supplied with the laser that may be mounted on the laser bench, or removed and post-mounted in a remote location by the user. This indicator illuminates in the same manner as described in paragraph titled "Remote Interlock Connector" on page 2-8. The detachable indicator is useful if the operator installs the OEM Evolution-15/30 in an instrument, and the indicator would not be clearly visible if attached to the laser bench. If the indicator is detached from the laser bench, it must be placed in a clearly visible location no more than 10 ft. (~ 3 m) from the Evolution-15/30 output port to maintain CDRH compliance.

All emission indicators remain on as long as the laser is capable of lasing. The indicators illuminate a few seconds prior to actual emission to give nearby personnel time to prepare for laser radiation emission.

Beam Safety Shutter

A solenoid-actuated safety shutter is mounted in the optical cavity to interrupt laser action when necessary. The shutter is actuated when the laser is turned on (either by pressing the ON button or by issuing a software command). The interlock fault and fail-safe mode is the closed position.

Output Port Shutter

A manually operated shutter mounted on the front laser output port is provided for blocking the beam, if required. If the optional side port is used, a metal disc (supplied) may be inserted in this port by the user to block emission.

Location of Controls

Controls for operation of the Evolution-15/30 laser are accessed through the control software via USB/RS-232 control so operators are not exposed to laser radiation during operation of the laser. If the

software is terminated, the computer malfunctions, or the USB/RS-232 connection is broken, the Evolution-15/30 will stop lasing within three seconds.

Operating Instructions

This manual contains instructions for operating and maintaining the Evolution-15/30 safely.

CDRH Requirements for Operating the Evolution-15/30 via USB/RS-232 Software Commands

The Evolution-15/30 and power supply comply with all applicable CDRH safety standards when operated via commands sent to the USB/RS-232 port on the front of the power supply cabinet. A software indicator indicates that laser energy is present or can be accessed.

Maintenance Required to Keep Laser in CDRH Compliance

This section presents the maintenance required to keep this laser product in compliance with CDRH Regulations.

This laser product complies with Title 21 of the *United States Code of Federal Regulations*, Chapter 1, Subchapter J, Parts 1040.10 and 1040.11, as applicable. To maintain compliance, verify the operation of all features listed below, either annually or whenever the product has been subjected to adverse environmental conditions (e.g., fire, flood, mechanical shock, spilled solvents). This maintenance is to be performed by the user, as outlined below.

- Verify that removing the laser cover closes the intracavity shutter and illuminates the interlock LED on the remote box and on the laser power supply.
- Verify that, when the cover interlock is defeated, the defeat mechanisms are clearly visible and prevent installation of the cover until they are removed.
- Verify that all the warning labels listed in Figure 2-1 to Figure 2-2, Evolution-15/30 Radiation Control Drawings, are present and firmly affixed in the correct locations.
- Verify that removing the user interlock connector on the back panel of the power supply prevents laser operation. Figure 2-4 shows the interlock with the jumper plug in place.

- Verify that the time delay between turn-on of the emission indicator and start of laser emission gives enough warning to allow action to avoid exposure to laser radiation.
- Verify that the internal beam attenuator (shutter):
  - Operates properly when the laser is turned off from the remote box (or remote computer controller, if being used)
  - Closes when the keyswitch is turned off
  - Blocks access to laser radiation

Sources of Additional Information

The following are some sources for additional information on laser safety standards and safety equipment and training.

Laser Safety Standards

Safe Use of Lasers (Z136.1)
American National Standards
Institute (ANSI)
1430 Broadway
New York, NY 10018
Tel: (212) 354-3300

Occupational Safety and Health Administration (OSHA)
U.S. Department of Labor
200 Constitution Avenue N.W.
Washington, DC 20210

A Guide for Control of Laser Hazards
American Conference of Governmental and Industrial Hygienists (ACGIH)
6500 Glenway Avenue, Bldg. D-7
Cincinnati, OH 45211
Tel: (513) 661-7881

Laser Safety Guide
Laser Institute of America
12424 Research Parkway, Suite 130
Orlando, FL 32826
Tel: (407) 380-1553

Equipment and Training

Laser Focus Buyer's Guide
Laser Focus World
One Technology Park Drive
P.O. Box 989
Westford, MA 01886-9938
Tel: (508) 692-0700

Photonics Spectra Buyer's Guide
Photonics Spectra
Berkshire Common
Pittsfield, MA 01202-4949
Tel: (413) 499-0514

Lasers and Optronics Buyer's Guide
Lasers and Optronics
301 Gibraltar Dr.
P.O. Box 650
Morris Plains, NJ 07950-0650
Tel: (210) 292-5100

CHAPTER THREE: INSTALLATION AND UTILITY REQUIREMENTS

Receiving the Evolution-15/30

The Evolution-15/30 power supply is in a cardboard box strapped inside a shipping crate.

To remove the power supply from the cardboard box:

1. Remove the clamps from the bottom edge of the crate
2. Lift off the top section of the crate
3. Remove the straps
4. Lift the cardboard boxes out of the crate. These boxes contain:
   - The power supply
   - Laptop computer
   - Accessories

The water chiller is strapped to the base of its shipping crate. To remove the chiller:

1. Remove the straps
2. Carefully lift the chiller off the base of the crate.

If any damage is evident, such as dents or scratches on the covers, broken knobs, etc., notify the carrier and an authorized sales representative immediately.

Keep the shipping crates. If damage is present and a damage claim must be filed, you may need them to demonstrate that the damage occurred as a result of shipping.

If the systems must be returned for service at a later date, the specially designed container will assure adequate protection.

The Evolution-15/30 can now be moved to the location in which it will be installed (see Chapter Four: Controls and Indicators).

Do not attempt to install the laser without a Coherent authorized personnel present, or remove the lid covering the optical cavity of the laser bench. Either action will void the warranty, and you will be charged for the repair of any damage incurred.

Installation

Location

Before installation, select a suitable location for the Evolution-15/30. The Evolution-15/30 is constructed using a temperature-stabilized monolithic body, but Coherent recommends that the laser be located in a laboratory-type environment that is free from dust and drafts, with low humidity (< 50%) and does not exhibit temperature fluctuations greater than ± 5°C.

Pumping a Legend Amplifier

When pumping a Legend regenerative amplifier, the Evolution-15/30 should be placed as close as possible to the Legend. The distance between the Evolution-15/30 and Legend is determined at the factory during the final test procedure. Relatively large deviations (> 1 ft. or 30 cm) from this distance can affect the overall performance of the system. For safety, it is also inadvisable to have an exposed laser beam travel long distances. Consult with an authorized service representative for further information.

Required Utilities

Do not apply AC power to the power supply chassis; this will activate the LBO crystal heater. Programming the crystal heater improperly will permanently damage the crystal. Such damage will not be covered under warranty.

The Evolution-15/30 power supply is compatible with 100-240 VAC and 50-60 Hz frequency; however, each Evolution-15/30 is optimized to operate at the customer-specified line voltage and frequency. Do not attempt to operate the Evolution-15/30 at a different voltage or frequency without consulting with an authorized service representative.

The closed-loop chiller supplied with the Evolution-15/30 is only compatible with a specific line voltage and frequency range. Do not attempt to operate the Evolution-15/30 chiller at a different voltage or frequency under any circumstances.

The Evolution-15/30 system requires the utilities listed in Table 3-1.

Table 3-1. Evolution Utility Requirements

DESTINATION	ACCEPTABLE LINE VOLTAGE / FREQUENCY (VAC/HZ)		CURRENT REQUIREMENTS (A)	
			LASER	CHILLER
USA	(110 ± 10) VAC, 60 Hz		15	15
JAPAN	OR	(110 ± 10) VAC, 50/60 Hz	15	15
		(220 ± 20) VAC, 50 Hz	10	10
EUROPE	(220 ± 20) VAC, 50 Hz		10	15

Installing the Power Supply

Consider the following when placing the power supply:

- Place the power supply within 10 ft. (3 m) of the laser bench to avoid straining the umbilical.
- If available, place the power supply in a ventilated 19-in. (48-cm) equipment rack.
- Allow 6 in. (15 cm) clearance to the front and back panels of the power supply cabinet and 3 in. (8 cm) on each side for proper airflow.
- Prevent the heated air exhaust from the back panel fans from returning to the intake on the back of the power supply or from exhausting toward the laser bench. Ensure adequate distance for good air flow, failure to do so will cause overheating in the power supply and instability in the laser output.
- Verify the interlock jumper plug is inserted at the back of the power supply. If the laser is to be used in a limited access area, remove the jumper and wire it to a safety switch. The switch must be wired such that when the device is actuated (a door is opened, for example), the switch opens and the laser turns off (see "Remote Interlock Connector" on page 2-8 of Chapter Two: Laser Safety).
- Verify that the local line frequency and voltage are within the acceptable input ranges.
- Ensure that all electrical cables and umbilical are routed safely and are not under any strain or compression.
- Verify that the power cable is secured with the built-in bracket on the AC socket on the power supply chassis.

Installing the Laser Bench

Note the following when placing the Evolution-15/30 laser bench:

- The laser bench is attached to the power supply chassis by a 10-ft. (3-m) umbilical consisting of four cable assemblies:
  - A 4-pin current cable
  - A 26-pin signal cable
  - One/Two BNC cable(s) that connect to the RF Out connector(s) on the rear of the power supply chassis
- Ensure that the weight of the umbilical does not drag the laser bench off the table or create a trip-hazard in the laboratory.

Identify the location of output port (front or side) at the time of installation so the service engineer can expedite the installation of the laser according to its intended purpose.

Secure the laser bench in a position on an optical table or other flat mounting surface as follows:

OEM Evolution-15/30:

Two slots are located at the center of the front and back of the laser housing for securing the laser bench. Use standard table screws (M6 or ¼-20) to fasten the laser to the table.

Ensure that the flexure arm at the front of the laser is bolted in place last; securing this first will defeat its purpose of allowing for thermal expansion/contraction of the housing.

Scientific Evolution-15/30:

Place the laser bench on the table and adjust the four mounting feet for the correct height, ensuring that the instrument is level. The height of the feet may then be locked in place using the locking ring on each leg. Secure the laser to the optical bench using a mounting clamp on each foot. If the laser is directed out the side port, remove the metal disk from the side of the Evolution 15/30 housing.

Installing the Control Computer

1. Position the Evolution-15/30 control computer within 10 ft. of the power supply chassis.

2. Set up the computer according to the manufacturer's instructions included in the computer box.
3. Connect the USB/RS-232 cable from the front of the Evolution power supply to the computer.

On control computers that ship with Windows 2000, the default user name is "Administrator", and the default password is "evolution" (passwords are case sensitive, and do not type the quotes). The control software is pre-installed on the control computer.

Installing the Chiller

When installing the chiller, observe the following instructions:

1. Check that the local line voltage and frequency is within the acceptable input range for the chiller supplied.
2. Place the chiller on the floor close enough to the Evolution-15/30 bench such that the cooling hoses will reach the system without causing undue strain.

Position the chiller so that its warm air exhaust is not drawn into the laser power supply and does not adversely affect the stability of the laser output.

3. To avoid hot air exhausting from one unit being drawn into the other, ensure that an air gap of at least 6 in. (15 cm) exists between the chiller and Evolution-15/30 power supply.
4. Do not place the chiller above the laser or power supply. (Should the unit be installed incorrectly and a leak develops, dripping water will damage the laser system.)
5. Attach the chiller hoses to the laser bench.

Note: The hose connectors are not polarized, so check that the feed line (marked with an arrow pointing towards the laser bench) is attached to the lower hose connector on the laser bench. This ensures that any air is purged upwards and out of the laser bench.

Before handling OPTISHIELD water treatment, read the Material Safety Data Sheet included in Appendix C that describes the potential hazards and handling precautions associated with this chemical. This chemical may be harmful if swallowed, inhaled, or absorbed through the skin or eyes.

Use only steam-distilled water in the Evolution-15/30 cooling system. The use of de-ionized or common tap water will cause damage to the entire system.

6. Add the contents of the one pint bottle of OPTISHIELD to the chiller reservoir.
7. Fill the chiller with high-quality, steam-distilled water.
8. Turn the chiller on and verify that water is flowing.
9. Inspect for leaks at the hose connections to the laser bench and at the chiller.
10. Turn the chiller off.

Note that it takes the chiller approximately 15 minutes to stabilize the temperature of the laser bench cold plate and therefore the output of the laser.
Leave the chiller on between periods of use if the laser is used frequently. This will eliminate the stabilization period. If the laser is used infrequently, turn the chiller off after use.

CHAPTER FOUR: CONTROLS AND INDICATORS

Product Overview

The Evolution-15/30 is designed around a Nd:YLF laser head pumped by AlGaAs (Aluminum Gallium Arsenide) laser diode arrays. The laser resonator is acousto-optically Q-switched at repetition rates from 1 to 10 kHz. In order to produce the maximum possible output power in the second harmonic, the laser uses intra-cavity frequency doubling with a non-critically phased-matched LBO crystal. Overall doubling efficiency is excellent, and the damage threshold of LBO is five times higher than other commonly used crystals, ensuring long-term trouble-free operation. Non-critical phase matching minimizes the angle sensitivity of the crystal for adjustment-free operation.

The Evolution-15/30 is ideally suited to pumping Ti:sapphire ultrafast amplifiers, and has been optimized as a pump source for the Legend and Libra Ti:sapphire regenerative amplifier systems.

Diode Pumping

The Evolution-15/30 employs laser diode pumping to excite the laser gain medium, as opposed to more conventional arc-lamp pumping schemes. Unlike the broadband light emitted by arc-lamps, the narrow spectral emission of laser diodes allows extremely efficient pumping of laser materials, with little or no diode light falling outside of the absorption band of the gain medium. This results in negligible waste heat generation.

The high efficiency results in low electrical- and cooling-utility requirements. The low waste heat generation also results in negligible deleterious thermal effects in the laser rod (such as thermal lensing and depolarization).

Another key advantage of laser diode pumping is that diodes offer lifetimes of many thousands of hours, compared to only hundreds of hours for arc-lamps.

Nd:YLF Laser Material

The Evolution-15/30 uses Nd:$LiYF_4$ (Nd:YLF) as its gain medium, which provides numerous advantages over other common neodymium-based lasers such as Nd:YAG. The long upper-state lifetime (470 µs) provides efficient energy storage for high-pulse energy operation a low repetition rates. The low thermal lensing and natural

birefringence of Nd:YLF enables scaling to higher power, avoiding the loss of beam quality and efficiency or the requirement for complex resonator designs.

With an intra-cavity polarizer one can select either the 1047 nm (extraordinary) or 1053 nm (ordinary) transition. All lines originate on the same Stark split $^4F_{3/2}$ upper level. The Evolution-15/30 lases on the 1053 nm transition because of the lower thermal lensing exhibited at this wavelength.

The relatively high thermal conductivity of Nd:YLF allows efficient heat extraction, and its natural birefringence overwhelms thermally induced birefringence, virtually eliminating the thermal depolarization problems found in optically isotropic hosts such as Nd:YAG.

Acousto-Optic Q-Switching

In acousto-optic Q-switching, an ultrasonic wave is launched into a block of transparent optical material. The photoelastic effect couples the modulating strain field of the ultrasonic wave to the optical index of refraction of the material. The resulting optical phase grating has a period equal to the acoustic wavelength and amplitude proportional to the sound amplitude.

When a light beam is incident upon this grating, a portion of the intensity will be diffracted out of the beam into one or more discrete directions. By choosing beam parameters properly, the diffracted beam can be deflected out of the laser cavity, thereby providing an energy loss that is sufficient to spoil the "Q" of the cavity.

The ultrasonic wave is launched into the Q-switch block by a piezoelectric transducer that converts incident electromagnetic energy into ultrasonic energy. The laser is returned to the high Q-state by switching the driving voltage to the transducer off. With no ultrasonic wave propagating through it, the fused silica block returns to its usual state of high optical transmission, the deflected beam disappears, and a Q-switched laser pulse is emitted.

Intra-Cavity Frequency Doubling

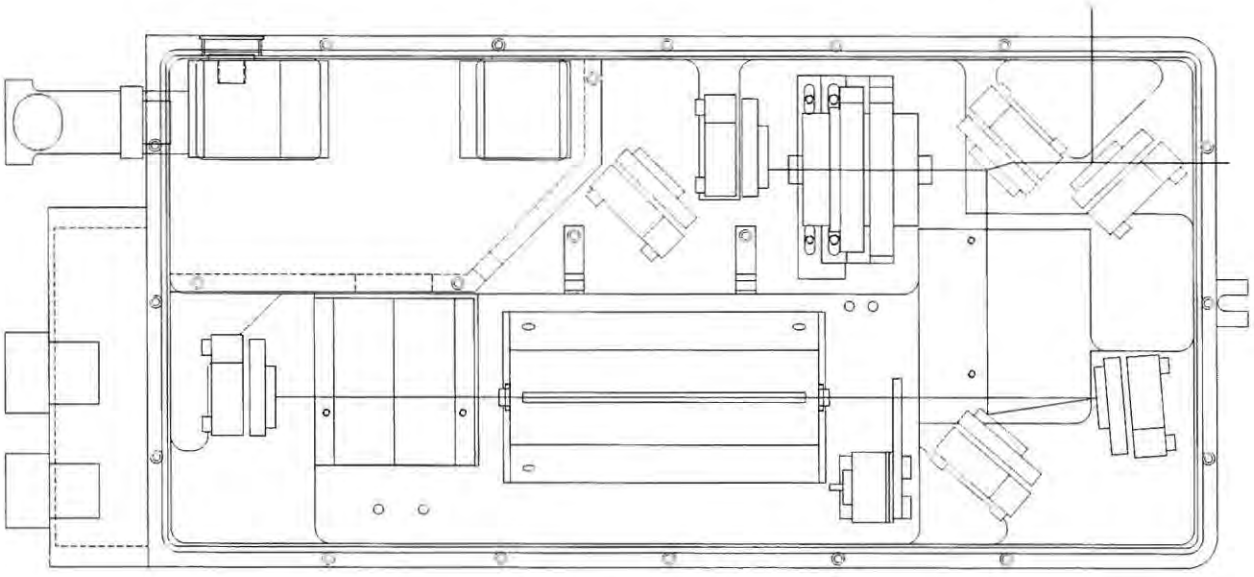
High-frequency conversion efficiencies require power densities that are not normally available from a CW-pumped laser. The solution to the problem employed by this laser is to place the non-linear doubling crystal inside the laser resonator, subjecting it to high circulating power. The power is coupled out of the resonator at the second-harmonic wavelength by replacing the output mirror with one that is 100% reflective at the fundamental and transmitting at the second harmonic wavelength. The second harmonic crystal acts as an output coupler in a manner analogous to the output coupler of a normal laser.

Because of the advantage of the high power density inside the laser cavity, it is only necessary to achieve a conversion efficiency equal to the optimum mirror transmission to convert the available output power at the fundamental completely.

Lithium Triborate (LBO)

LBO is a nonlinear optical crystal characterized by good UV transparency, a relatively high optical damage threshold, and a moderate non-linear optical coefficient. The birefringence in LBO is small, which enables non-critical phase matching and provides a larger acceptance angle for high efficiency frequency-conversion. These properties, with its mechanical hardness, chemical stability, and non-hygroscopic nature, make LBO an ideal material for nonlinear optical frequency conversion.

Optical Laser Bench Configuration



EVOLUTION-15/30

Figure 4-1. Optical Laser Bench

The optical laser bench of the Evolution-15/30 is shown in Figure 4-1. The laser resonator is in a folded configuration, which enables efficient output coupling of the second harmonic light and

reduces the overall size of the Evolution-15/30. All mirrors are high reflectivity at 1053 nm unless otherwise noted. From left to right, the optical cavity consists of the following components:

- 0°, curved rear-cavity mirror
- Diode-pumped laser head
- Intracavity safety shutter
- 0° curved intracavity mirror
- Acousto-optic Q-switch (Ev-30 only)
- 45° turning mirror
- Acousto-optic Q-switch
- 45° intracavity dichroic folding mirror (high reflector at 1053 nm, high transmission at 527 nm)
- LBO frequency-doubling crystal in temperature-stabilized oven
- 0° curved end mirror (high reflector at 1053 nm and 527 nm)

The laser head contains the Nd:YLF laser rod and laser diodes. The diodes provide optical excitation to the laser rod and lasing between the cavity mirrors is established. The 1053 nm radiation is contained entirely within the laser resonator because there is no output coupler at this wavelength.

The laser is Q-switched (typically at 1 to 10 kHz), producing intra-cavity laser pulses of duration 100 to 350 ns, depending on the pulse energy.

Because of the high intra-cavity radiation fluence, the 1053 nm radiation is converted to 527 nm in the LBO crystal.

This 527 nm light transmits through the dichroic mirror, and exits the laser bench directly from the forward output port, or reflects from a turning mirror and exits through the side output port. The beam waist is located at the 0°, a flat-end mirror, so the beam diverges at either output port of the laser. A lens is located at the output port to collimate the beam.

Component Description

Laser Pump Chamber

The Nd:YLF laser rod and laser diodes are contained in the laser pump chamber. The pump chamber is mounted to the laser bench in a mechanically indexed bracket that allows for easy extraction and insertion of the pump chamber. The laser rod is held with O-rings in a water flow-tube. A gold-coated reflector surrounds the flow tube; slits in the reflector allow the passage of the pump light from the laser diodes. Both the laser rod and laser diodes are water-cooled in parallel by the internal cooling system that enters the pump chamber through O-ring sealed ports in the base of the pump chamber.

The diodes are arranged in three blocks of two/four (two for Ev-15, four for Ev-30) high-power diode bars that share a single water-cooled heat sink and electrical connections. Three blocks of diodes are mounted 120° apart down the length of the laser rod. The diodes are connected electrically in series to the Evolution-15/30 diode driver through a high-current connector on the pump chamber.

Q-Switches

The Q-switch is enclosed in a metal housing and mounted on a riser block with a coarse azimuthal adjust. The Q-switch is made of high-quality fused silica to which an RF transducer is bonded. The fused silica is cut and polished optically to be optically oriented at Brewster's angle for S-polarized intra-cavity laser radiation.

Approximately 20-30 W RF power is delivered to the Q-switch through a 50Ω BNC cable. The Q-switch is water-cooled, and has a built-in temperature interlock to shut the RF power off if an over-temperature condition occurs. The power supply for the Q-switch is located in the Evolution-15/30 power supply chassis.

LBO Crystal and Oven

The LBO crystal is located in a crystal housing that maintains its set temperature in the range 315° F (157° C) to 340° F (171° C) to within 0.10° F (0.056° C). At this temperature, the crystal is non-critically phase-matched for the intra-cavity 1053 nm radiation, ensuring high conversion efficiency to the second harmonic. The crystal should be maintained constantly at this temperature, even when the laser is not in use. If necessary, the crystal can be ramped down to room temperature for long-term storage of the laser (see "Long-Term Shutdown" on page 5-4). The LBO crystal is anti-reflection-coated for both 1053 nm and 527 nm.

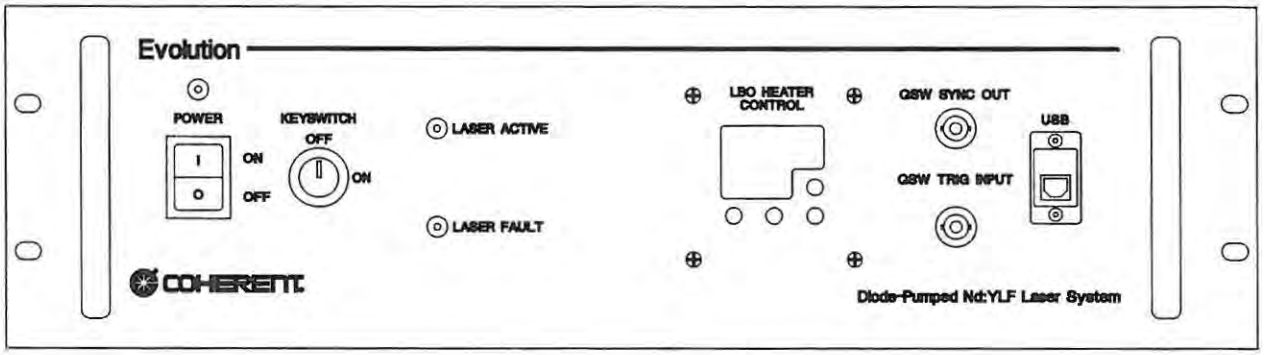
The temperature controller is a microprocessor-based device and is pre-programmed. It can maintain the crystal to within 0.10° F (0.056° C), which ensures stable operation of the laser. If the LBO temperature is not maintained at the factory set-point, an interlock will prevent laser operation.

Power Supply

The power supply assembly consists of a rugged steel frame in a 19-in. (48-cm) rack-mount configuration. The power supply contains the master control board, diode power supply, Q-switch RF driver, LBO crystal temperature controller, and various control electronics. In general, it should not be necessary to access any components inside the power supply.

Removing the power supply cover will expose the user to electrical hazards. Potentially lethal voltages and currents are contained in the power supply. Normal operation of the Evolution-15/30 does not require access to the power supply circuitry. Contact an authorized service representative before attempting to correct any problem with the power supply.

Power Supply Front Panel



EVOLUTION-15/30

Figure 4-2. Power Supply Front Panel

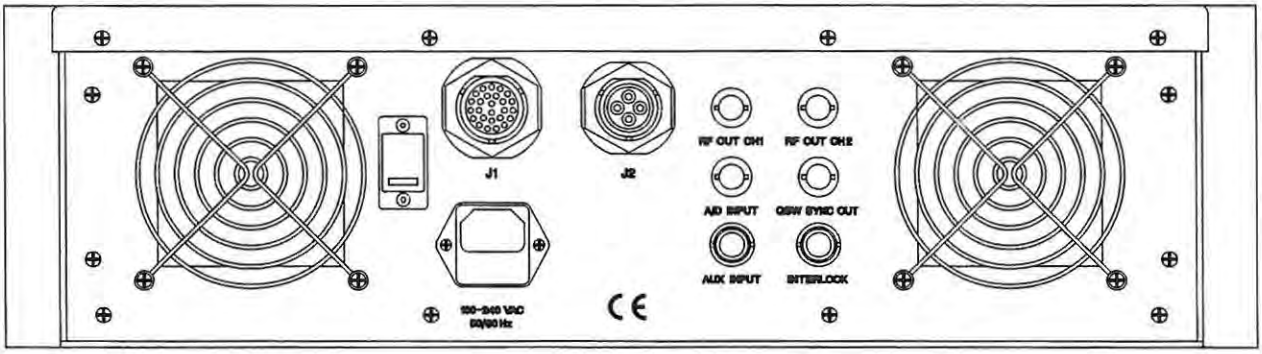
Table 4-1. Power Supply Front Panel

CONTROL	FUNCTION
Powerswitch	Enables main AC power to the power supply. Green LED illuminates when AC power is activated.  **AC power to the LBO crystal heater circuit in the power supply is always present when the power supply is plugged in, even when the AC breaker is deactivated.**
Keyswitch	Functions as an interlock. In the OFF position it prevents operation of the laser. The keyswitch is designed such that the key can be removed only in the OFF position. The keyswitch is also used to reset latched interlocks by cycling from the OFF position to the ON position.
Laser Active	Illuminates when current is flowing through the laser diode arrays, regardless of the state of the laser output (Q-switched, CW, hold-off, etc.)
Laser Fault	Illuminates when the Evolution encounters an interlock fault.
LBO Heater Control	Maintains the temperature of the LBO crystal oven. Normally it is not necessary to change the settings of this controller.
USB/RS-232 I/O	Connects the USB/RS-232 port of a computer to control the laser.

Table 4-1. Power Supply Front Panel (Continued)

CONTROL	FUNCTION
QSW SYNC OUT	Provides a fixed TTL synchronization signal (in BNC output) that is coincident with the triggering of the Q-switch.
QSW TRIG INPUT	The Evolution Q-switch can be triggered externally by applying a TTL voltage levels (i.e. 4-5 V) and a trigger pulsewidth of around 5 µs for 1 kHz operation and 2.5 µs for 5 kHz operation. Adjust the trigger pulsewidth for optimal power and pulsewidth. The input is terminated with high impedance; if the external triggering source has a 50-Ω line drive output, a 50-Ω terminator should be added at the QSW TRIG INPUT input to avoid multiple pulses from ringing. External triggering of the laser is possible. Using this mode requires the user to select EXT trigger mode in the control software. **Note: External triggering outside the tested / manufactured rep rate is not recommended and may cause damage to YLF rod or LBO optics.**

Power Supply Rear Panel



EVOLUTION-15/30

Figure 4-3. Power Supply Rear Panel

Table 4-2. Power Supply Rear Panel

CONTROL	FUNCTION
AC IN	Main input power required must be in the range 100to 240 VAC ± 10%, 50/60 Hz. Fuses meeting the following specifications are used: Line Voltage — 200 to 240 VAC — 100 to 120 VAC F1/F2: 3AG SLO BLO® — 10 A/10 A — 15 A/15 A
RF OUT (Ev-15/30)	BNC output, 20-30 W, 100-150 V RMS sine wave at 27.11 MHz into a 50Ω load, used to do drive the Evolution Q-switch. DO NOT connect these signals to anything other than the supplied BNC connectors in the umbilical to the Evolution laser bench.

Table 4-2. Power Supply Rear Panel (Continued)

CONTROL	FUNCTION
26-pin connector (unlabeled on Ev-15-30)	Supplies interlock and control signals to the laser bench. Connects to the 26-pin umbilical cable.
4-pin connector (unlabeled on Ev-15-30)	Supplies current to the laser diode arrays in the laser bench. Connects to the four-pin umbilical cable.
Interlock	Three-pin connector used for interlocking the laser to a controlled access point, such as a laboratory door. Shorting pins J1 and J2 (shown in Figure 2-4) enable laser operation.
AC IN	Main input power required must be in the range 100 to 240 VAC ± 10%, 50/60 Hz.
A/D INPUT	Reserved for future use.
AUX INPUT	Used to enable CW operation for testing. (Note: the software has to be enabled in CW mode and the factory password setting enabled to test in CW mode).

Electronic Control Module

The Evolution-30 Electronic Control Module (ECM) is a USB/RS-232 control device for setting and monitoring the laser diode power supply, the laser interlocks, and the Q-switch driver. The ECM is controlled via USB/RS-232 by software on the supplied laptop computer.

Laser Diode Power Supply

The laser diode power supply is a completely self-contained unit, enclosed in a metal housing to provide protection for the power supply components and to service personnel. The Evolution-15/30 power supply operation is controlled and monitored by the ECM.

Q-Switch Driver

The Q-switch driver provides RF power to the one/two Q-switch(es) on the optical laser bench. It is an all solid-state electronics driver, consisting of a crystal-controlled oscillator, double-balanced modulator, pulse generator with gate, and broad-band power amplifier that provides > 20 W drive power into each Q-switch. The Evolution-15/30 Q-switch driver is controlled and monitored by the ECM.

LBO Crystal Temperature Controller

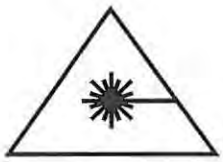
The LBO doubling crystal is temperature tuned for non-critical phase matching. The LBO is housed in a temperature-stabilized oven. A resistive heating element, combined with a local temperature sensor, is used with the heater controller to stabilize the crystal

temperature to within ± 0.1° F (0.056° C). The heater controller is programmed to limit the rate at which the crystal temperature is changed (typically no faster than 10° F (5.6° C) per minute) to prevent the crystal anti-reflection coatings from cracking.

The power for the temperature controller is wired directly to the AC lines so the crystal stays heated, even when the front-panel breaker is turned off. The LBO crystal temperature should be ramped down before disconnecting power to the chassis. See "Long-Term Shutdown" on page 5-4, in Chapter Five: Daily Operation for instructions.

LBO crystal temperature controller [WATLOW] is pre-programmed at the factory. It should be unnecessary for any customer adjustment of the WATLOW controller during normal operations.

CHAPTER FIVE: DAILY OPERATION



Safety glasses for all lasing wavelengths must be worn at all times when operating this or any laser system. Consult your laser safety officer to select appropriate safety glasses. See "Chapter Two: Laser Safety".

Current Settings

The Evolution-15/30 comes with a set of performance data that gives the factory-measured output power as a function of laser diode current at the nominal Q-switch rep-rate specified when the laser was ordered. When the laser is installed, the authorized service rep will verify these measurements.

Coherent recommends establishing at least three nominal current settings: a low, medium, and high setting produce, for example, 4 W, 8 W, and 12 W for a standard 1 kHz Evolution-15 system. In this chapter, these current settings will be referred to as low, medium, and high.

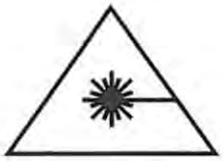
If the Evolution-15/30 is not normally operated at its maximum specified output power, scale these settings appropriately when following the procedures in this chapter and in the troubleshooting chapter at the end of the manual.

After several hundred hours of operation, the laser diode output power will decrease slightly. The maximum possible current setting is set at the factory to ensure that each laser will meet its specification power for thousands of hours of operation.

Start-up Procedure

Diode Start-up and Lasing Initiation

The following procedures should be used during normal start-up and operation of the Evolution-15/30 laser system.



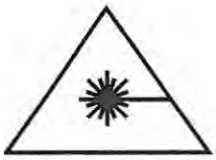
The following procedure will result in a laser beam emitting from the Evolution-15/30 output port. Ensure all persons in the room are wearing adequate laser eye protection. Ensure that the anticipated beam is safely terminated into a high-power beam block or power meter.

1. Plug in the power supply chassis and connect the umbilical cables according to specifications.
2. Verify that the LBO heater control temperature is at the proper factory-set temperature.
3. Turn the external cooling water supply on.
4. If the control computer was disconnected, reconnect the cable between the control computer and the power supply chassis.
5. Boot the computer and log in (if necessary).
6. Set the power switch on the power supply chassis to the ON position.
7. Insert the key into the keyswitch and turn to the ON position.
8. Launch the Evolution-15/30 control software on the control computer.
9. After the control software communicates with the Evolution-15/30 and all interlocks are met, the STOP indicator will light, indicating that laser can be started.

   Note: If the FAULT indicator on the power supply chassis is blinking, or if the FAULT state indicator on the control software is illuminated, see the trouble-shooting guide for assistance in clearing the interlocks.
10. Set the Current Control in the control software to the nominal low current setting.
11. If the Evolution-15/30 is to be internally Q-switched, set the QSW Frequency control to the proper rep-rate (e.g., 1.0 kHz), and set the QSW MODE switch to INTERNAL.
12. If the Evolution-15/30 is to be externally Q-switched, connect a TTL-level signal (at least 1 µs duration) at the proper frequency to the EXT QS TRIG IN connector on the front panel of the power supply chassis, and set the QSW MODE to EXTERNAL. Q-switch operation is synchronized to the rising edge of the input pulse.

The Evolution-15/30 was optimized at a specific Q-switch repetition rate. Operating the laser at a significantly different rate may result in decreased performance or optical damage.

13. Rotate the output shutter open on the front of the Evolution-15/30. Ensure that the laser output will be directed into an appropriate termination (e.g. beam dump, power meter, Ti:sapphire rod, etc.)



The following procedure will result in a laser beam emitting from the Evolution-15/30 output port. Ensure all persons in the room are using adequate laser eye protection. Ensure that the anticipated beam is terminated properly.

14. Slide the Laser State slider to the RUN position. The LASER ACTIVE LED on the power supply chassis will illuminate, as will the LASER ACTIVE LED and the FIRE LED in the control software. The Current Monitor will ramp up to the set-point current in approximately five seconds.
15. Measure the output power with a power meter capable of measuring at least 100 Watts. Within several minutes, the 527 nm power should be the same or close to the power that was previously measured at the low current setting.
16. Manually increase the current setting at a rate of no more than 1 A per second to the medium current setting. Monitor the power continuously while increasing the current to ensure a monotonic increase in power with current.

    If the power is low, wait ten minutes for the laser temperature to stabilize.

    When the power reaches the value corresponding to the medium setting, increase the current to the high setting and verify the power.

    If the beam does not reach operating power it may be necessary to optimize the lasing output as described in "Chapter Seven: Maintenance and Troubleshooting".

System Shutdown

1. Slide the Laser State switch to STOP in the control software. The shutter will close and the diodes will shut off immediately.
2. Close the control software window.
3. Turn the key in the keyswitch to the OFF position.
4. Remove the key from the keyswitch.
5. Turn the main power switch off.
6. Turn the water chiller off.

Long-Term Shutdown

If the Evolution-15/30 must be disconnected from line voltage for an extended period of time, the LBO crystal temperature must be ramped down slowly to room temperature to avoid thermal shock to the crystal. Use the following procedure.

1. Press and hold the down arrow (lower right) on the LBO Heater Control until the temperature setting is 75°F or from the control software change the LBO software, change the LBO setting to 75°F.
2. Allow the crystal temperature to ramp down until it reaches 75°F.
3. Turn the Evolution-15/30 power supply off and disconnect the power cord.
4. To return the Evolution-15/30 to normal operation, plug in the power supply and reset the temperature to the factory-set temperature. When the LBO crystal reaches the set point, the laser can be operated normally.

CHAPTER SIX: EXTERNAL CONTROL COMPUTER

The Evolution-15/30 comes with a commercial laptop computer and software to control and monitor the functions of the laser via USB/RS-232 interface. Because of frequent changes in the availability of specific computer models, the particular computer delivered with each laser may vary in brand and features, but in general, it will have a Pentium-class processor $\geq$400 MHz, $\geq$32 MB of RAM, $\geq$2 GB hard drive, a CD-ROM drive. The control software for the Evolution-15/30 is pre-installed and tested with each laser, and is also delivered on CD-ROM.

The Evolution-15/30 was built and tested using the control computer and control software that shipped with the laser. Coherent does not endorse or support the use of other computers or software to control the Evolution-15/30; doing so may void the warranty and/or cause damage to the laser.

USB/RS-232 Connection

The control computer is connected to the Evolution-15/30 power supply using the included USB/RS-232cable.

Control Software

The included control software for the Evolution-15/30 is called "Evolution-15/30 Control", and is accessed by a shortcut in the "Programs" folder in the "Start" menu. The exact layout of the front panel varies depending on the version of the software, but all versions of the software share the same general controls. The latest version of the software is available by contacting an authorized service representative.

This chapter describes the controls for the Version 4.1.6 of the software.

Main Controls

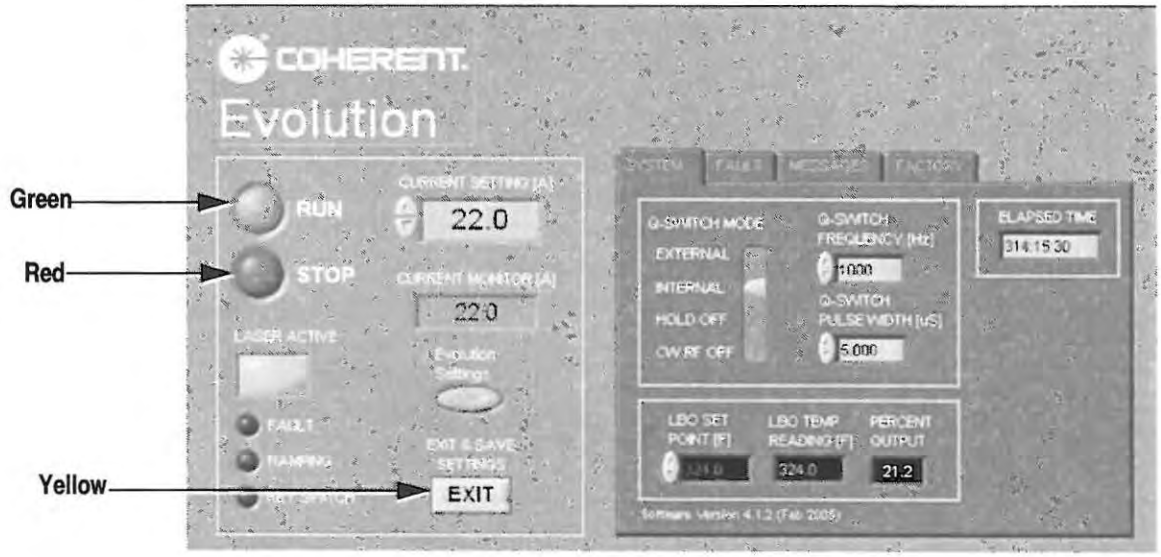


Figure 6-1. Evolution Control Software

Table 6-1. Main Controls

CONTROL	FUNCTION
RUN/STOP	Button control (on the software, not the front panel of the power supply); changes the state of the Evolution-15/30. **RUN.** The laser diodes turn on and the Evolution-15/30 starts lasing. **COUNTDOWN.** If the RUN state is entered from the STOP state, COUNTDOWN will occur before lasing begins, during which time a tone will emit and the LED on the power supply and laser bench will flash. **STOP.** The Evolution-15/30 stops lasing. **FAULT.** This state is initiated if the interlock circuit is tripped; in this state, the laser cannot be put into the RUN state until the interlock is cleared and keyswitch on the front of the power supply is cycled off and on.
Run/Stop/Fault /Count Down /Ramping	LED indicators; describes the Evolution-15/30 state (see above).
Keyswitch	LASER FAULT LED indicator; describes the state of the access control key: Illuminated = The key is in the OFF position Flashing = The keyswitch must be recycled to reset the FAULT state
Laser Active	LED indicator on the front panel of the power supply; illuminates when current is supplied to the laser diodes.
Current Setting	Numeric control accessed via software; sets the output current of the laser diodes (in A) up to the factory limit set point. The setting can be entered directly, or incremented by 0.1 A using the adjacent buttons. When the current setting is increased, the current will ramp up to the setpoint at a factory-set rate (max 0.3 A/sec), and the Countdown LED will illuminate. When the current setting is decreased, the current will decrease immediately without ramping.
Current Monitor	Software-driven numeric/meter indicator; monitors the current (A) detected by the power supply.
Evolution Settings	Button control accessed via software; shows or hides additional controls and indicators.
Exit & Save	Button control accessed via software: Stops the laser (if running) Stops execution of the control program Saves the settings

SYSTEM Panel

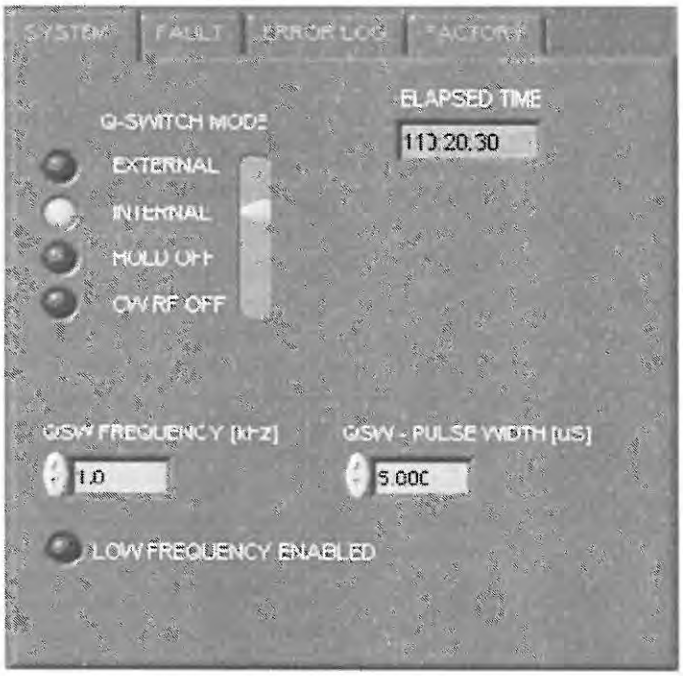


Figure 6-2. Control Software SYSTEM Panel

Table 6-2. Control Software SYSTEM Panel

CONTROL	FUNCTION
QSWMODE	Slider control to set the mode of the Q-switch driver and LED indicators to show the active Q-switch mode.
	Changing Q-switching modes is not possible while the laser is in RUN mode.
INTERNAL	RF power on, Q-switch trigger source is the internal clock on the interanl main circuit board, rep-rate set by the software QSW Frequency control.
EXTERNAL	RF power on, Q-switch trigger source is the EXT QS TRIG IN BNC on the front panel of the power supply. The external trigger frequency must be > 500 Hz, or the laser will interlock.
HOLD OFF	RF power on, no Q-switch trigger(s). Used to check alignment of the Q-switch(es) during construction and servicing of the laser.
CW RF OFF	CW RF power off. Used for setting and checking laser cavity alignment during construction and servicing of the laser.
QSW Frequency [kHz]	Numeric control to set the frequency of the internal Q-switch trigger source.
QSW Pulse Width [µs]	Numeric control to set the width of the internal trigger pulse to the Q-switch driver.
Elapsed Time	Numeric indicator of the elapsed cumulative hours and minutes of laser operation.
Low Frequency Enable	Boolean indicator that the low frequency mode has been enabled (see control on Factory panel), and the QSW LOW FREQ interlock has been disabled.

FAULT Panel

Figure 6-3. Control Software FAULT Panel

Table 6-3. Control Software FAULT Panel

CONTROL	FUNCTION
COVER/USER	Illuminated if any of the micro-switches on the Evolution-15/30 laser bench are not engaged, or if the user interlock is open. Check covers or interlock defeats on laser bench and door interlock switch or interlock defeat, then cycle keyswitch to clear.
FLOW	Illuminated if the water flow from the chiller is less than 4 GPM. Check chiller function, water pressure, reservoir level, and water hoses to ensure adequate flow, then cycle keyswitch to clear.
LBO TEMP	Illuminated if the LBO temperature is outside a 2° window around the factory set point. Allow temperature to return to specified temperature range.
QSW LOW FREQ	Illuminated if the QSW MODE is EXTERNAL and the external source of triggers drops below 500 Hz. Ensure that the source of external Q-switch triggers is producing TTL pulses at 500 Hz or higher. Note that this interlock is disabled if the ENABLE LOW FREQUENCY control (factory panel) is in the ON position.
QSW TEMP	Illuminated if the thermal sensor in the Q-switch exceeds safe operating temperature. Check chiller function, water pressure, reservoir level, water hoses, and water contamination, then cycle keyswitch to clear.
QSW VSWR	Illuminated if the Q-switch driver detects a significant amount of power reflected from the Q-switch. Check cable connections between the power supply and the laser head. Also check for adequate water flow, then cycle keyswitch to clear, and change to INTERNAL or EXTERNAL Q-switch triggering to test for error. If the problem persists, contact an authorized service representative.
COMM ERROR	Illuminated if communications are interrupted between the computer and the Evolution-15/30 power supply. Check USB/RS-232 cable connections and ensure that the power supply is turned on. Exit the control software, cycle the AC on the power supply, and restart the control software to clear.

Table 6-3. Control Software FAULT Panel (Continued)

CONTROL	FUNCTION
DRIVER TEMP	Illuminated if the temperature of the Diode Drive (FET) heat sink becomes overheated due to inadequate airflow to the driver, or a shorted or "over current" condition. Check airflow of the power supply and allow it to run without lasing for at least 10 minutes, then restart the laser.
DIODE TEMP	Illuminated if the temperature sensor located inside the laser head and mounted on the diode array heat sink exceeds safe operating temperature. Turn off power supply, allow the chiller to run for 10 minutes, then restart the laser, running at a lower current.
CLEAR FAULTS	Enables the user to clear any latched faults – an alternative to cycling the keyswitch.

ERROR LOG Panel

The ERROR LOG panel records all fault conditions, fault corrections, and their timestamps. The path and file name of the error log is shown in the top text box. The faults are shown in the lower text box. A new error log file is created each calendar day with the date included in the file name in YYYYMMDD format.

Figure 6-4. Control Software ERROR LOG Panel

FACTORY Panel

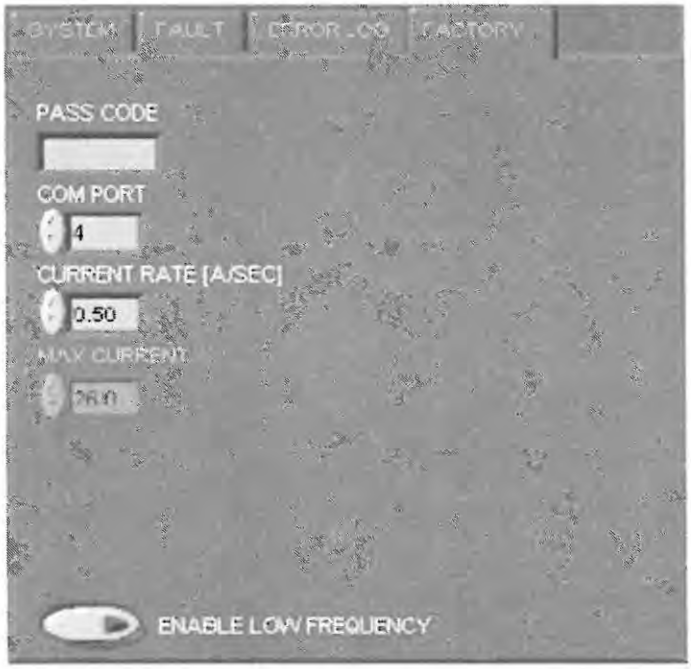


Figure 6-5. Control Software FACTORY Panel

Figure 6-6. Control Software FACTORY Panel

CONTROL	FUNCTION
PASS CODE	Factory use only.
COM PORT	Sets the computer USB/RS-232 communications port (user settable).
CURRENT RATE [A/SEC]	Current ramp rate in A per second. The operational range is 0.05 to 0.3 A/sec. The default is 0.3 A/sec. Do not exceed 0.3 A/sec.
MAX CURRENT	Maximum current setting for the laser diodes; set at the factory.
ENABLE LOW FREQUENCY	Enables the Evolution to operate at Q-switch trigger frequencies below 500 Hz (only available on power supplies shipped in 2003 or later). This control is set to the OFF condition each time the program is started.

The Evolution should only be operated at frequencies below 500 Hz if the LBO temperature has been optimized for operation at 1 kHz or below. If the Evolution has been optimized for operation at a higher rep rate (e.g., 5 kHz), operating at lower rep-rates could cause optical damage.

CHAPTER SEVEN: MAINTENANCE AND TROUBLESHOOTING

Maintenance/ Service

The Evolution-15/30 has been designed for minimal and easy maintenance. However, certain routine operations are recommended to maintain the system in good operating order. For more information, contact an authorized service representative.

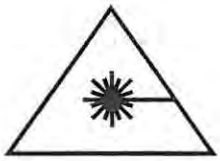
The maintenance and/or service of the laser must be performed either by Coherent personnel or by persons authorized by Coherent. Maintenance and/or service by unauthorized persons results in all warranties being voided. Coherent assumes no liability for any damages and malfunctions caused by disregarding or ignoring this information.

Lasing Optimization

Cavity Mirror Adjustments

All of the optical mounts in the Evolution-15/30 are securely fastened to the rigid base plate of the optical laser bench, which is temperature-stabilized. Nevertheless, the mirrors may become slightly misaligned due to severe changes in room temperature, bumps or shocks, or other stresses on the optical bench. Under these circumstances, the end-mirrors of the Evolution-15/30 laser cavity may require adjustment.

Improper adjustment of the Evolution-15/30 laser can result in damage to the laser rod, LBO crystal, or Q-switch. Do not attempt to adjust the Evolution-15/30 mirrors without a full and complete understanding of the procedures outlined in this chapter. Contact an authorized service representative for more details or to answer any questions.



Laser protective eyewear MUST be worn to protect the eyes from all wavelengths emitted by the Evolution-15/30. (See Chapter Two: Laser Safety.)

The following procedure may be used to optimize the cavity mirrors.

Materials required:

- Laser safety goggles
- Infrared viewer or card
- Two 1/8" ball-tipped Allen wrenches
- Calibrated power meter capable of measuring at least 100 W

Procedure:

1. If the Evolution-15/30 is operating, stop the lasing output by sliding the Laser State switch to STOP button. (Pushing it is not necessary to turn off the power to the power supply chassis.)
2. Lift the sheet metal cover from the Evolution-15/30 optical laser bench.
3. Locate the two interlock defeat plates (with orange warning labels), and use them to lock down the cover interlock switches. These defeats allow the Evolution-15/30 to be operated with the sheet metal cover removed. They must be removed and the cover replaced as soon as the optimization procedure has been completed.
4. Cycle the keyswitch on the power supply chassis to clear the cover interlock circuit.
5. Place the power meter at the Evolution-15/30 output.
6. Set the QSW MODE to INTERNAL and the QSW frequency to the last operational frequency, typically 1 or 5 kHz.
7. Start the laser at the low current setting, allow the power to stabilize, and make note the stable power level.
8. Remove the set screws covering the mirror adjustment ports on the side of the housing. Place the screws in a safe place.
9. Using the Allen wrenches, carefully adjust the vertical adjustment screw of the end-mirror while monitoring the power. Make **very small adjustments** (less than 1 turn total travel).

Use this process to maximize the output power, and make a note of the maximum stable power.

10. Using the same procedure, carefully adjust the horizontal adjustment screw while monitoring the power. Again, make **very small adjustments** (less than 1 turn total travel). Use this process to maximize the output power, and make a note of the maximum stable power.

11. Set the laser state switch to STOP and set the QSW MODE switch to HOLD OFF.

12. Set the current to the low setting. Set the power meter to its most sensitive reading. Slide the laser state switch to RUN to start the Evolution-15/30, and ensure there is no visible or IR laser output (using an IR viewer or IR card).

Note: If there is some laser output, STOP, turn the laser off, and contact an authorized service representative for assistance.

13. Slowly turn the current up to the high setting while monitoring the laser power. The laser power must remain zero all the way up to 21 A or 22 A.

    Check for visible or infrared output (with an IR viewer or card).

If there is any laser output at the high setting, STOP, turn the laser off, and contact an authorized service representative for assistance.

14. Monitor the power meter and make **small** (< 1/4 turn) adjustments to the horizontal adjustment screw of the end mirror in both directions around the set point, and return the screw as close as possible to its starting point.

    Make the same adjustment scan for the vertical adjustment screw on the same mirror.

If any lasing is detected at any time during these adjustments, STOP, turn the laser off, and contact an authorized service representative for assistance.

15. If no lasing was measured in the preceding step, turn the current back down to the low setting at which the mirrors were optimized.
16. Stop the laser with the laser state switch, and slide the QSW MODE selector to INTERNAL.
17. Restart the laser with the laser state switch. Note the output power.
18. Fine-tune the vertical and horizontal adjustment screws on the mirror to return the output power to the maximum value previously recorded.
19. Once the power is optimized, slowly turn the current control up to the medium current setting and then to the high current setting while monitoring the power meter. When the current setting is high, allow the laser to stabilize, and note the stable power level.

If at any time the laser power starts to fluctuate rapidly, STOP, turn the laser off, and contact an authorized service representative for assistance.

If this procedure does not enable the Evolution-15/30 to meet its specified power, it may be necessary to optimize the LBO crystal temperature.

LBO Crystal Temperature Optimization

Depending on environmental conditions, the optimum temperature of the LBO crystal for efficient intra-cavity doubling may vary from the factory set point.

The LBO crystal temperature can be varied ±1° F from the factory-set temperature.

If, at any time, the Evolution-15/30 output power drops by more than 2 W while optimizing the LBO temperature at the medium current setting, turn the laser off immediately. (If the LBO temperature is severely detuned and insufficient second harmonic light is coupled out of the optical resonator, optical damage may occur.) Reduce the current to the low setting, perform the optimization procedure described in the next section, then slowly increase the current to the medium setting to check for optimized performance. Contact an authorized service representative for assistance, if necessary.

If the temperature of the LBO heater deviates from the factory setting by more than 1° F, an LBO TEMP Fault will occur. In this event, return the setting to the factory setting, and restart the optimization procedure in the opposite temperature direction. If the optimum LBO temperature setting is more than 1° away from the factory setting, contact an authorized service representative.

To Optimize the LBO Temperature:

1. Note the factory temperature setting in the laser test document that shipped with the laser.
2. Note the present temperature setting if different from the factory setting.
3. Set the current to the medium setting.
4. Turn on the laser.
5. Allow it to stabilize for 10 minutes.
6. Make a note of the power reading with a power meter.
7. While monitoring the power, use the up and down arrows on the LBO HEATER CONTROLLER to change the temperature set point by 0.5° F.
8. After the temperature stabilizes at the new setting, note the power.

   If the power has increased, change the temperature by another 0.5° F in the same direction (up or down).

   If the power has decreased, set the temperature 0.5° F in the opposite direction.

9. Repeat step 8 until power is maximized.
10. When the output power is maximized, make a note of the temperature setting for future reference.

Cleaning Optics

The Evolution-15/30 is sealed against dust and debris, but, depending on the cleanliness of the environment, it is possible that some dust may get into the optical laser bench.

Cleaning the Evolution-15/30 optics may result in misalignment of the laser cavity. After cleaning, the cavity must be realigned using the procedure in this chapter.

Cleaning the optics will require the optical cavity to be opened. This procedure must not be executed without prior approval of an authorized service representative. Unauthorized opening of the seal will void the warranty, and may damage the laser.

The Evolution-15/30 is assembled with chemically cleaned parts. To prevent contamination, do not work inside the housing unless wearing latex gloves, finger cots, or the equivalent.

Materials Required:

- Safety goggles
- Plastic gloves or finger cots
- Scientific-grade lens cleaning tissue (Kodak brand or equivalent quality)
- Reagent-grade methanol or acetone
- Eyedropper
- Hemostat (surgical pliers)
- English hex-wrench set
- Bright lamp or flashlight

The LBO crystal is kept above 320° F (160° C). Prolonged contact with the LBO crystal housing can burn skin, melt plastic, and ignite flammable material.

Never attempt to clean the LBO crystal or the Nd:YLF laser rod in this system. Optical damage will occur and the warranty will be voided if these two optics have been manipulated in any way. If optical damage has occurred or cleaning of these optics is necessary, contact an authorized service representative.

Accessing the Evolution-15/30 Optics

1. Turn the Evolution-15/30 power supply off.
2. Remove the screws holding the metal cover in place and remove the cover.
3. Put the screws in a safe place.
4. Remove the lid and place it on a clean surface.

Mirrors

Mirrors must be cleaned carefully with soft optical tissue and reagent-grade methanol or acetone as described below.

1. Always wash hands first in order to remove all dirt and oil residues and wear finger cots or gloves at all times optics are handled.
2. Attempt to remove any surface contamination from the optic with either a blower brush or gentle stream of dry, filtered nitrogen or air. This will remove any particulates that would otherwise be dragged across the optic's surface if cleaning with solvent is necessary. Ensure that the contamination is not merely blown onto another optical surface.
3. If solvent cleaning is necessary, hold one sheet of lens tissue over the optic to be cleaned.
4. Using an eyedropper, place a single drop of spectroscopic-grade methanol or acetone on top of the lens tissue.
5. Drag the lens tissue across the optic once only.
6. If a residue of solvent is left on the optic, repeat the procedure using less solvent and a new lens tissue until no residue remains.

For Hard-to-Reach Optics

1. Wear finger cots or gloves.
2. Fold a piece of lens tissue repeatedly to form a pad approximately 1 cm wide.

3. Hold the pad with a pair of hemostats so 3 mm of the folded edge protrudes from the hemostat blades.
4. Saturate the pad with spectroscopic-grade methanol or acetone and shake to remove excess solvent.
5. Reach slightly below the center of the optic and wipe the surface of the optic toward the outside in one motion. Be careful that the tip of the hemostats does not scratch the optic.
6. Repeat the operation with a clean tissue on the other faces of the optic.

Q-Switch

The Q-switch can be difficult to clean; attempt to clean only if dust or debris is clearly visible. When cleaning the Q-switch crystal faces, it is easier to remove the U-shaped cover around the Q-switch in order to gain unobstructed access to the quartz faces.

Routine Maintenance - Cooling Water

To prevent metal corrosion and algae growth in the closed loop cooling water system of the Evolution-15/30, Coherent recommends using OPTISHIELD corrosion inhibitor. This chemical treatment prevents galvanic corrosion from dissimilar metals and prevents oxidation of ferrous metals in the system, and acts as an effective algaecide. The first-time application of OPTISHIELD is normally performed at the factory when the Evolution-15/30 is manufactured. Coherent recommends changing the OPTISHIELD solution every 6 months for most systems.

Follow the procedure below to change OPTISHIELD in the cooling water system.

Before handling OPTISHIELD water treatment, read the Material Safety Data Sheet included in Appendix C that describes the potential hazards and handling precautions associated with this chemical. This chemical may be harmful if swallowed, inhaled, or absorbed through the skin or eyes.

Use only steam-distilled water in the Evolution-15/30 cooling system. The use of de-ionized or common tap water may cause corrosion damage.

Directions for New Systems, First-Time Use

1. Flush the cooling circuit with distilled water.
2. Fill cooling system with distilled water-leaving 5% volume for OPTISHIELD.
3. Calculate system capacity/volume in gallons. (Example: 1 gallon (3.8 L) of OPTISHIELD to 20 gallons (75.7 L) of water for first "coating cycle")
4. Add OPTISHIELD to the distilled water.
5. Circulate this solution for about 30 minutes.
6. Drain fluid. DO NOT RINSE!
7. Fill cooling system with distilled water, leaving 10% volume for OPTISHIELD.
8. Add OPTISHIELD to the distilled water. (Example: 1 gallon (3.8 L) of OPTISHIELD to 10 gallons (37.9 L) of water)

Directions, After First-Time Use

Every 6 months

1. Drain used fluid from the chiller.
2. Flush the chiller with clean distilled water.
3. Change particle filter.
4. Add 1 pint of OPTISHIELD water treatment (Coherent Part # 470-9345).
5. Fill the chiller with steam-distilled water.
6. Run the system.
7. Refill the reservoir after the water lines and head have filled with water.

Use only steam-distilled water. The use of de-ionized or common tap water may cause corrosion damage.

8. The system is ready for use.

Troubleshooting

This section contains a general user-troubleshooting guide. It is provided to assist in isolating some of the problems that might arise while using the system.

A complete repair procedure is beyond the scope of this manual. For information concerning repair by Coherent, see Appendix titled "Warranty" or contact an authorized service representative.

Troubleshooting Guide

Use this guide if Evolution-15/30 performance drops unexpectedly. If you take corrective measure and are unable to bring the Evolution-15/30 performance up to specification, call an authorized service representative for assistance.

Table 7-1. Symptom: Laser Will Not Start

POSSIBLE CAUSES	CORRECTIVE ACTION
No AC power	Check that the green "AC Power" LED is illuminated. If not, check that the breaker on front of the power supply is in the correct position. Check that the power cord at rear of power supply is tight. Check fuse.
Interlocks not met	Check interlock display on power supply. If there are lighted interlock LEDs, turn keyswitch off and back on to clear latched interlocks. Investigate any interlocks that are not cleared by this action (e.g., make sure the chiller is turned on and the hoses are not constricted, make sure the cover is on, make sure the user interlock is in place, etc.). See Chapter Four: Controls and Indicators, for more information about each interlock.
Keyswitch not in ON position	Turn the keyswitch to the ON position (vertical). The key cannot be removed when it is in the ON position.
Communications error with laptop	Check for good connection of USB/RS-232 cable. Exit Evolution-15/30 control software application. Switch AC power on the Power Supply to OFF. Wait 5 seconds. Switch AC power ON. Re-launch Evolution-15/30 control software application.

Table 7-2. Symptom: Variations In Output Power

POSSIBLE CAUSES	CORRECTIVE ACTION
LBO crystal temperature has drifted	Check the output power across the tuning range of the LBO crystal for the highest output power, as described in Chapter Seven: Maintenance and Troubleshooting.
Water temperature variation	Make sure that the water chiller temperature is adjusted to the correct temperature that was set when it was installed (typically in the range 62°F (17°C) to 81°F (27°C).
Cavity optics out of alignment.	The cavity mirrors can be adjusted slightly to optimize the output power. Read the detailed instructions in Chapter Seven: Maintenance and Troubleshooting, before attempting to adjust the mirrors.
Optics are dirty	Inspect the optics for dirt or contamination. If dirty, clean the optics as described in "Cleaning Optics" on page 7-6.
Q-switch breakthrough	With the current at the high setting, turn the QSW MODE selector to the HOLD OFF position, and turn the laser on. Using an infrared viewer or card, check that there is no infrared and/or visible output beam from the laser. If there is any laser power, the Q-switch is malfunctioning or misaligned. Contact an authorized service representative for assistance.

Table 7-3. Symptom: Emission Light Comes On, But No Output

POSSIBLE CAUSES	CORRECTIVE ACTION
Output shutter is closed	If front port is being used, rotate shutter open. If side port is being used, check that the metallic disc has been removed.
QSW MODE set to HOLD OFF	Check the setting of the QSW MODE selector in the SYSTEM panel of the control software.
Cavity optics are out of alignment.	If the cavity optics are so severely misaligned that the laser will not start, call an authorized service representative for assistance.

Table 7-4. Symptom: Power Is Below Specification

POSSIBLE CAUSES	CORRECTIVE ACTION
Diode current set too low	Verify the expected output power for the low-, medium-, and high-power settings.
Q-switch frequency set too high or too low	Power output depends on Q-switch frequency. If the Evolution-15/30 is operated at a different Q-switch frequency than specified at time of order, contact an authorized service representative for the power specification at that particular frequency.
Cavity optics misaligned	The cavity mirrors can be adjusted slightly to optimize the output power. Read the detailed instructions in "Cavity Mirror Adjustments" on page 7-1 before attempting to adjust the mirrors.
LBO crystal temperature has drifted	Check the output power across the ±1° tuning range of the LBO crystal for the highest output power.
Algae growth in cooling water	Follow maintenance procedure given in the paragraph titled "Routine Maintenance – Cooling Water" on page 7-8.
Diode power is low	After several thousand hours of operation, the optical power of the laser diodes decreases, and the current to the diodes must be increased to compensate. Contact an authorized service representative for assistance.

Table 7-5. Symptom: Laser Does Not Q-Switch or CW Laser Output

POSSIBLE CAUSES	CORRECTIVE ACTION
External Q-switch input not valid	If an external Q-switch signal is used, ensure that the signal is at least 4 V with ~ 4 µs duration adjusted for maximum power output. Ensure the frequency is set to the manufacturer tested rep rate (e.g. 5 K or 10 K).
QSW MODE set to CW RF OFF	Change setting of QSW MODE control to INTERNAL.
QSW BNC cable removed	If the QSW cable is removed, the Evolution-15/30 will report a VSWR error and change to the CW RF OFF QSW MODE. Verify that the BNC cables is attached at the power supply and laser bench.

APPENDIX A: DOUBLE-PULSE OPTION

Overview

The Double-Pulse Option (DPO) produces two closely spaced, high-energy laser pulses at repetition rates up to 10 kHz for applications in high-speed imaging and Particle Image Velocimetry (PIV). This Appendix explains the theory of operation, a set-up and operation procedure, and a troubleshooting guide.

The Evolution-DPO incorporates hardware and software that enable the Evolution laser to produce dual laser pulses at repetition rates from 1 kHz to 10 kHz. The relative timing of the laser pulses can be adjusted from 1 to 150 µs using the integrated software. The energy of each of the pulses in the pair can also be controlled by the software (nominally adjusted to be identical in the two pulses). The total energy of the two pulses depends on the repetition rate and the model of Evolution laser.

Theory of Operation

The Evolution is normally operated as a single-pulse, Q-switched laser, commonly at a repetition rate of 1 kHz. Q-switching refers to the process of changing the laser intra-cavity losses from a high value, in which the laser does not emit laser light, to a low value, in which a pulse of laser light can be emitted. The Evolution is Q-switched by an acousto-optic device (referred to as the "Q-switch"), in which an acoustic wave is resonantly driven by a transducer driven by an RF amplifier.

The output of the RF amplifier is modulated on and off by a trigger input. When no voltage is applied to the trigger input, the RF output is applied to the Q-switch, and the cavity loss is high. When a positive logical high voltage is applied to the trigger input, the RF output shuts off. (A more detailed explanation of the operation of the Q-switch can be found in the Chapter Five: Daily Operation.)

In normal operation, a trigger pulse is applied to the Q-switch driver with a duration that is long enough to extract all of the stored energy in the laser rod, (typically a few microseconds). The duration of the laser pulse is determined by several factors including the laser gain, the cavity length, and the output coupling. The typical pulse duration of the Evolution is around 150 ns to 200 ns(for a 20 mJ pulse at 1 kHz).

The energy normally extracted in a single pulse can be extracted in two pulses by adjusting the duration of the Q-switch trigger pulse. This is the principle upon which the Evolution-DPO is based. In the

simplest terms, two trigger signals are applied: the first pulse extracts half the available stored laser energy, and the second extracts the remaining energy after a user-selected delay time.

In more detail, the first pulse allows the laser to begin to extract energy from the laser rod, but then turns the Q-switch back on (preventing lasing) before all of the energy is extracted. After some delay (e.g., 1-150 µs), a second trigger pulse is applied, and the laser then depletes the remaining energy.

Typically the difference in the laser gain between the two pulses results in different pulse durations between the first and second pulse.

There are several advantages to this method of generating a double pulse compared to conventional dual-laser-head technology:

- Both pulses are produced by the same resonator, ensuring that they are collinear and have the same polarization
- A single resonator has fewer components, is simpler to align, and is more compact
- The ratio of energy in the two pulses can be adjusted easily by adjusting the duration of the first trigger pulse
- The timing between the two laser pulses can be adjusted easily by adjusting the timing between the two trigger pulses
- The laser can be operated at any repetition rate that the Evolution can operate, with simple adjustments of the trigger pulses to ensure a consistent energy ratio between laser pulses
- The technique of dividing the energy into two pulses can be extended to more than two pulses by adding and adjusting more trigger pulses (contact Coherent for more information about this option).

System Description

The DPO electronics are contained in a 1U rack-mount enclosure (Figure A-1) designed to be mounted in the same rack as the Evolution power supply. The front panel contains three connectors:

- **Trigger In (BNC).** Input for TTL level external trigger signal (not 50-Ω terminated).
- **Trigger Out (BNC).** Produces double-pulse TTL level signal capable of driving 50-Ω load. Normally connected to "External Q-switch Trigger Input" on Evolution power supply.
- **USB/RS-232 (type-A female).** Connects to laptop computer using supplied USB/RS-232 A-male to A-male cable.

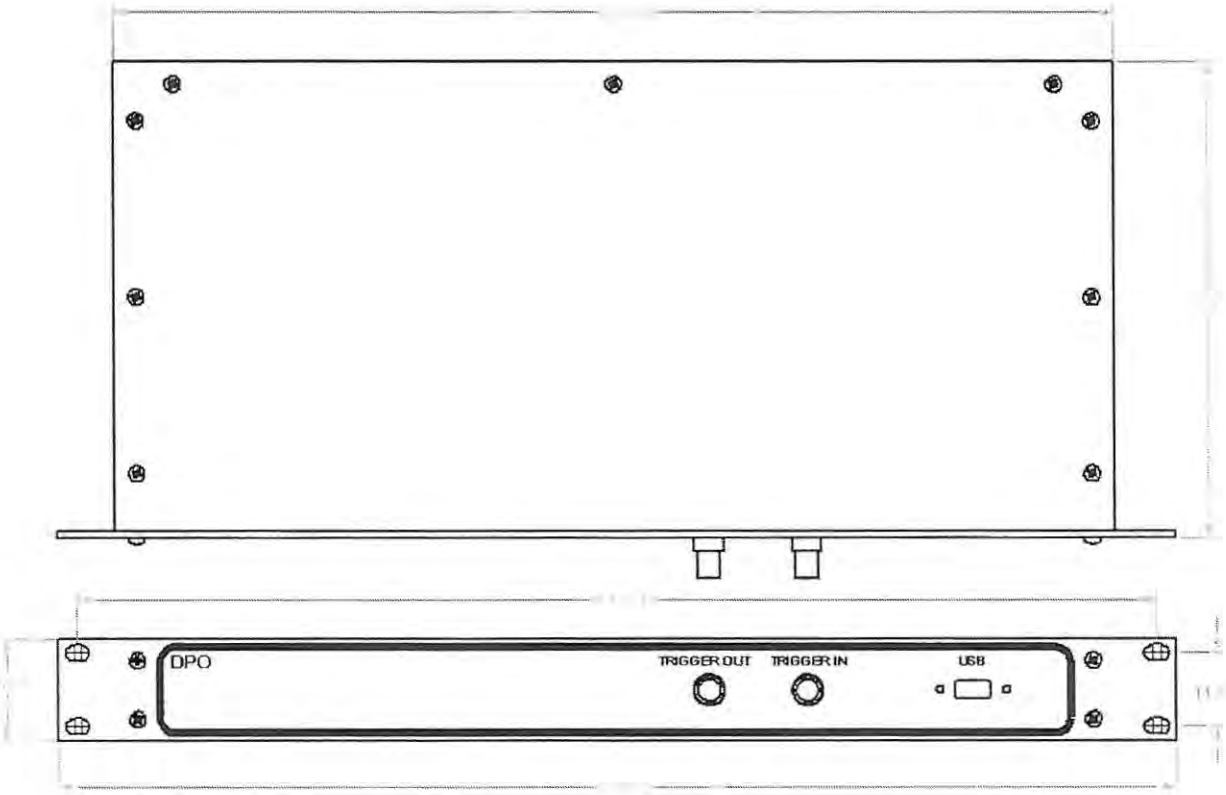


Figure A-1. DPO Electronics Enclosure

Evolution DPO Connections and Controls

The connection diagram for the DPO is shown in Figure A-2. The user provides a single TTL trigger signal at the repetition rate of the laser (e.g., 1 kHz). This trigger pulse is connected to the input of the DPO electronics, which produces the trigger signal for the Evolution laser required to generate double-pulse output at the same repetition rate as the input trigger.

The user external trigger source should produce a clean, TTL-level trigger signal at the desired repetition rate of the dual-pulse output. If the trigger source has a 50 Ω line driver output, a 50 Ω terminator should be added to the input of the DPO. The DPO electronics are triggered off of the rising edge of the input trigger, and pulses with duration as short as 20 ns have been tested to work properly.

The DPO is controlled by a modified version of the standard Evolution control software. The general description of the Evolution control software is provided in Chapter Six: External Control Computer; this chapter only describes the controls for the DPO, shown in Figure A-3. The control parameters for the DPO electronics are:

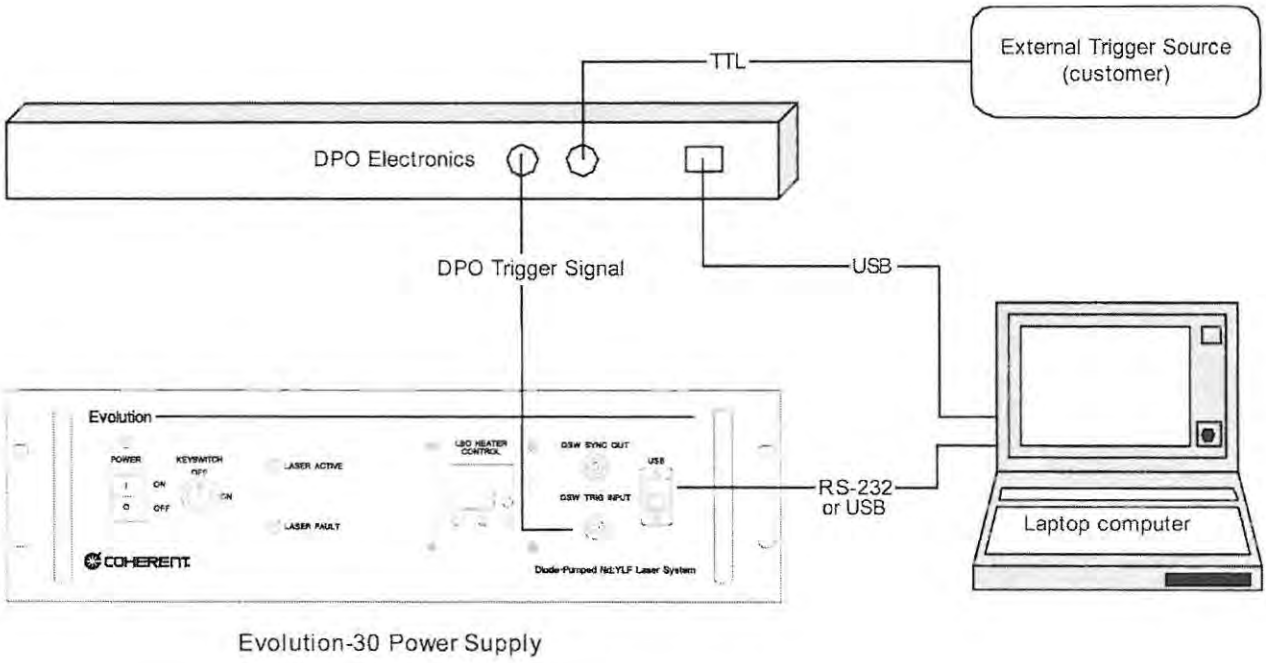


Figure A-2. Interconnection Diagram for Evolution-DPO

- **T1 [uS].** Numerical control of pulse width of first DPO trigger pulse in microseconds
- **T2 [uS].** Numerical control of pulse width of second DPO trigger pulse in microseconds
- **Delay [µS].** Numerical control of timing delay between the falling edge of T1 and the rising edge of T2 in microseconds
- **DPO Output.** Toggle switch control to enable or disable the DPO output triggers (enabled by default)
- **DPO Err.** Indicator illuminated when the control software detects an error or is unable to communicate with the DPO electronics

Note that the Evolution Q-Switch Mode is set to EXTERNAL, which is required for DPO operation.

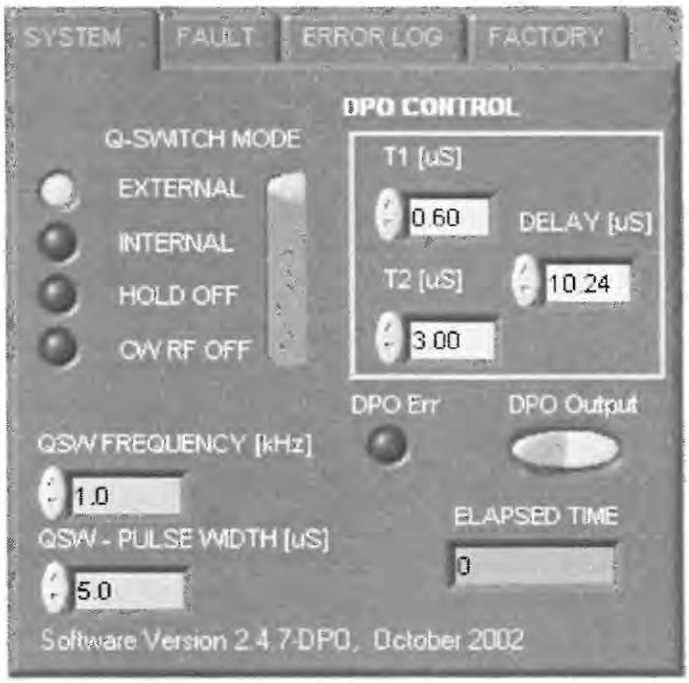


Figure A-3. Control Panel in Evolution-DPO Control Software Showing DPO Controls

The range of values for the DPO timing signals is shown in Table A-1.

Table A-1. Range and Increment for DPO Timing Signals

SIGNAL	MINIMUM [µS]	MAXIMUM [µS]	INCREMENT [µS]
T1	0.2	2.55	0.01
T2	0.3	5.1	0.02
Delay	1.28	163.2	0.64

There is an internal delay of ~ 5 ns with a jitter of up to 10 ns between the rising edge of the input trigger and the rising edge of T1. Note that there will be a delay between the rising edges of T1 and T2 and the respective laser pulses. This delay is caused by the time required for the laser to Q-switch after the start of the trigger, and varies depending on the energy per pulse and repetition rate of the laser.

DPO Laser Operation

Characterize Single-Pulse Performance

Before operating the Evolution laser in DPO mode, it is important to have a good operating knowledge of the laser in its single-pulse mode of operation. Ensure that the user is familiar with the operating principles and procedures provided in this manual. Specifically, the user should record the standard laser operating parameters (diode current, LBO temperature, and output power) at several different power levels for each repetition rate at which it is planned to run the laser in DPO mode. This data can be taken by triggering the Evolution with INTERNAL Q-switch mode and using the standard chiller temperature and LBO temperature provided with the Evolution at the time of installation. An example of these parameters is listed in Table A-2.

Table A-2. Example Laser Parameters and Output Power for Single-Pulse Operation of an Evolution-30 at 1 kHz Repetition Rate

DIODE CURRENT [A]	AVERAGE POWER (1 KHZ) [W]	CHILLER TEMP [° C]	LBO TEMP [° F]
17.0	7.8	20	323.0
20.0	13.5	20	323.0
24.0	21.5	20	323.0

Connect DPO Signals

1. Connect the supplied USB/RS-232 cable to the DPO electronics and to the Evolution control computer.
2. Connect the external trigger signal to the TRIGGER IN BNC on the DPO box using a 50 Ω BNC cable.
3. Connect the TRIGGER OUT BNC to the External Q-switch Trigger Input on the Evolution power supply using a 50-Ω BNC cable.

   Note: if a 50-Ω in-line terminator was supplied with the DPO electronics, attach it in-line with the BNC cable at the Evolution power supply.
4. Start the Evolution-DPO control software and verify that the "DPO Err" indicator is not illuminated.

5. Start the Evolution at a low current setting (e.g., 10 A), and verify that the laser does not indicate any interlock faults. If the trigger signals are not connected correctly, the QSW LOW FREQ interlock will trip.

Setting DPO Timing Parameters

In this chapter it is assumed that the performance will be optimized to provide equal energy in each of the two laser pulses (P1 and P2). The value of timing parameters for equal pulse energy in DPO operation depend fundamentally on the repetition rate of the laser, the delay between the pulses, and the pump level of the laser. Some general guidelines for setting the parameters are:

- For a given repetition rate, pump level, and delay setting, the balance of energy between P1 and P2 is controlled by the value of T1
- At low repetition rates (e.g., below 5 kHz), the value of T2 can ordinarily be set to its maximum value (5.1 μs)
- At higher repetition rates (e.g., 5 kHz and above), the value of T2 can be optimized to give higher average output power, but cuts off the long, low energy tail of the second pulse
- At all repetition rates, as the delay between pulses is increased, the energy in P2 increases, due to the additional pump energy absorbed during the delay time between pulses
- Because the laser gain is higher before P1, the full-width-half-max (FWHM) pulse width of P1 will always be shorter than the FWHM of P2
- The maximum average output power of the Evolution in DPO mode may be somewhat lower or higher than the average power in single-pulse mode, depending on the repetition rate and the delay between pulses
- The exact timing of the peaks of T1 and P1 and of T2 and P2 will vary at different pump powers and repetition rates; in general, the delay between T2 and P2 will be greater than the delay between T1 and P1

If the Evolution was originally provided with the DPO option, a set of DPO timing parameters measured at the factory was provided with the laser. If the DPO option was ordered separately, refer to the sample parameters listed in Table A-3. (**Note:** In both cases, these parameters are intended to provide a starting reference point; final optimization of the DPO parameters must be performed by the customer for each individual application of the laser.)

Table A-3. Example DPO Parameters and Output Power for Operation of an Evolution-30 at 1 kHz Repetition Rate

CURRENT [A]	AVERAGE POWER (1 KHZ) [W]	T1 [µS]	DELAY [µS]	T2 [µS]
17.0	8	1.02	100	5.1
20.0	12.5	0.80	100	5.1
24.0	20	0.70	100	5.1
17.0	7.5	0.95	50	5.1
20.0	12	0.80	50	5.1
24.0	19	0.70	50	5.1
17.0	7.2	0.95	10	5.1
20.0	11.6	0.80	10	5.1
24.0	18.4	0.70	10	5.1
17.0	7.2	0.95	1.28	5.1
20.0	11.5	0.80	1.28	5.1
24.0	18	0.70	1.28	5.1

Pulse Energy Measurement

To measure the energy balance between P1 and P2 precisely, an instrument capable of resolving the energy of each pulse individually is required. In the event that an instrument capable of direct, high-rep-rate, precisely timed energy measurement is not available, the next-best option is to use the integrated exposure of triggered frame-captures from a high-speed charge-coupled device (CCD) camera.

A somewhat simpler method is to use a fast (few nanosecond rise-time) photodiode and a high-speed digital oscilloscope to monitor an indirect reflection of the DPO output. In this arrangement, the energy of each DPO pulse is proportional to the integrated photodiode signal; i.e., the area under the photodiode trace in units of volt-seconds. Many digital oscilloscopes can measure the area of a signal directly. Alternatively, the signal can be captured and the area can be integrated numerically or manually. Because the photodiode traces of P1 and P2 are approximately triangular, half the product of the peak voltage and the FWHM gives a reasonable first-order approximation of the area.

Note that the sum of the energies of P1 and P2 in DPO mode will be slightly lower than the pulse energy in single-pulse mode at the same repetition rate and diode current. This can be explained by the fact that the gain for P2 is always lower than for P1, resulting in lower extraction efficiency for P2. Furthermore, if the delay between P1 and P2 is relatively long (e.g., 100 µs), the gain for P1 will also be reduced by the decreased pump duration between the end of P2 and the start of P1.

DPO Parameter Optimization: Energy Measurement Method

Assuming a photodiode is being used to monitor the signals, use the following procedure to set the energy of P1 and P2 equal.

1. Determine the average output power level needed for the experiment, and set the laser parameters (LBO, diode current) according to the single-pulse parameter table.
2. Place a power meter and photodiode at the output of the laser.
3. Set the delay to the desired value between the two pulses.
4. Set T2 to the maximum at 5.1 µs (assuming low repetition rate operation).
5. Set T1 close to the reference value in the table provided for the Evolution, or to the value given in the example reference data in this manual.
6. Turn the Evolution on and set the current to the operating value.
7. Measure the area of the photodiode signal for P1 and P2.
8. Adjust the value of T1 in 10-ns increments, and re-measure the area of each pulse after each adjustment.
9. Adjust T1 until the two areas are almost the same, which means the energy of the two pulses are about the same.
10. If the total power must be increased, increase the pump current.
11. Repeat the above adjustment of T1 to get the same energy for each pulse.
12. If the system is operating at higher repetition rates (> 5 kHz), decrease the value of T2 while monitoring the average power.
13. When the average power is maximized, readjust T1 to get the same energy for each pulse.

DPO Parameter Optimization: Average Power Measurement Method

At lower repetition rates (e.g., 1 kHz), a simpler method can be used to get approximately equal energy for each pulse by measuring the average power.

1. Place a power meter at the output of the laser.
2. Set the delay to the desired value between the two pulses.
3. Set T1 and T2 at the reference value in the table provided for the Evolution, or to the value given in the example reference data in this manual.
4. Turn the laser on and ramp the current up to the operating power level; measure the average power.
5. Reduce T2 to its minimum setting (0.3 µs).
6. Adjust T1 until the power is about half of the power measured in step 4.
7. Increase T2 to the maximum setting (5.1 µs). If the average power doubles from step 6, the energy in P1 and P2 should be about the same.

APPENDIX B: MATERIAL SAFETY DATA SHEETS

This Appendix contains the material safety data sheet (MSDS) that is supplied by the vendor of the chemical algaecide that is used in the Evolution-15/30 laser closed loop cooling system. Read the MSDS carefully before handling or disposing of the chemical (or cooling water containing the chemical) described therein. The information contained in the MSDS description is applicable exclusively to the chemical substance identified therein and for its intended use and to the unit quantity intended for that purpose. The information does not relate to, and may not be appropriate for, any applications or larger quantity of the substance described. The product is intended for use by individuals possessing sufficient technical skill and qualification to use the material with suitable discretion and understanding of the risk of handling any potentially hazardous chemical.

This information has been obtained from sources believed to be reliable and accurate but has not been verified independently. Accordingly, NO REPRESENTATION OR WARRANTY, EXPRESSED OR IMPLIED, WITH RESPECT TO MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE is made with respect to the information contained in the MSDS. For further information, contact the manufacturer at the address listed on the MSDS sheet.

MATERIAL SAFETY DATA SHEET: OPTISHIELD

DATE REVIEWED: **June, 1999**

DISTRIBUTOR:

OPTI TEMP INC.
P.O. Box 5246
Traverse City, Michigan
49696

Telephone: 231-946-2931
Emergency Hot Line
Chem-Tel 800-255-3924
International 813-977-3668 (Collect)

USE OF PRODUCT: Treatment of select cooling water systems.

SECTION I. Product Identification

Special Components Chemical Names

This is a proprietary blend that contains the following components:

Name	% In Product
Sodium Nitrate	< 1%
Sodium Molybdate	1-2%
Sodium Hydroxide	1-2%
Phosphoric Acid	< 1.5%
Triazole	< 2.5%

The Hazardous Materials Index Rating is as follows: Health=1; Flammability=0; Reactivity=1

SECTION II. Physical Data

- % Volatiles: Nil
- Color: Light Golden-Yellow
- Odor: Mild
- Specific Gravity: 1.03
- Solubility: 100% in water
- pH of 100% solution (concentrated) 11 to 12; typical 11.5

SECTION III. Fire and Explosion Hazard

- Non-Flammable
- Flash Point: Unknown

MATERIAL SAFETY DATA SHEET: OPTISHIELD

SECTION IV. Reactivity Data

- Stability: Stable
- Polymerization: None
- Exposure to Other Chemicals: Keep away from concentrated acids
- Reactivity in Water: None

SECTION V. Shipping Information

Regulation: This material is not a DOT regulated material.

This product is a freezable liquid when and where applicable.

SECTION VI. Spill

Small spills: Small spills may be soaked up using common absorbent material, and using appropriate safety equipment. Dispose of and handle in accordance with local, state, and federal regulations.

Large spills: Large spills must be pumped into suitable containers located in diked areas. Residual material must be cleaned up with water. Dispose of and handle in accordance with local, state, and federal regulations.

SECTION VII. First Aid

- **Ingestion**: Give milk or water, induce vomiting, and get medical attention.
- **Skin**: Flush with fresh water, wash with soap and water. Remove contaminated clothes and shoes.
- **Eyes**: Flush with fresh water for at least 15 minutes. Get medical attention.
- **Inhalation**: Inhalation must not occur during normal operation. However, should it occur, close container and move to well-ventilated area. If irritation persists, get medical attention.

SECTION VIII. Special Instructions

- Do **NOT** pressurize container.
- Keep container closed at all times when not in use.
- Store in cool area above 60° F. Do not allow fluid to freeze.
- Use in well-ventilated area. Do not breathe mist or vapor.
- Wash hands thoroughly after handling product.
- Protect eyes with safety goggles or glasses with side shields.

WARRANTY

Coherent, Inc. warrants to the original purchaser (the Buyer) only, that the laser system, that is the subject of this sale, (a) conforms to Coherent's published specifications and (b) is free from defects in materials and workmanship.

Laser systems are warranted to conform to Coherent's published specifications and to be free from defects in materials and workmanship for a period of twelve (12) months. This warranty covers travel expenses for the first ninety (90) days. For systems that include installation in the purchase price, this warranty begins at installation or thirty (30) days from shipment, whichever occurs first. For systems which do not include installation, this warranty begins at date of shipment.

Optical Products

Coherent optical products are unconditionally warranted to be free of defects in materials and workmanship. Discrepancies must be reported to Coherent within thirty (30) days of receipt, and returned to Coherent within ninety (90) days. Adjustment is limited to replacement, refund or repair at Coherent's option.

Conditions of Warranty

On-site warranty services are provided only at the installation point. If products eligible for on-site warranty and installation services are moved from the original installation point, the warranty will remain in effect only if the Buyer purchases additional inspection or installation services at the new site.

For warranty service requiring the return of any product to Coherent, the product must be returned to a service facility designated by Coherent. The Buyer is responsible for all shipping charges, taxes and duties covered under warranty service.

Parts replaced under warranty shall become the property of Coherent and must be returned to Coherent, Inc., Santa Clara, or to a facility designated by Coherent. The Buyer will be obligated to issue a purchase order for the value of the replaced parts and Coherent will issue credit when the parts are received.

Other Products

Other products not specifically listed above are warranted to, (a) conform to Coherent's published specifications and (b) be free from defects in materials and workmanship. This warranty covers parts and labor and is for a period of twelve (12) months from the date of shipment.

Responsibilities of the Buyer

The Buyer must provide the appropriate utilities and operating environment outlined in the product literature and/or the Preinstallation Manual. Damage to the laser system caused by failure of Buyer's utilities or the Buyer's failure to maintain an appropriate operating environment, is solely the responsibility of the Buyer and is specifically excluded from any warranty, warranty extension, or service agreement.

The Buyer is responsible for prompt notification to Coherent of any claims made under warranty. In no event will Coherent be responsible for warranty claims later than seven (7) days after the expiration of the warranty.

Limitations of Warranty

The foregoing warranty shall not apply to defects resulting from:

1. Components or accessories with separate warranties manufactured by companies other than Coherent.
2. Improper or inadequate maintenance by Buyer.
3. Buyer-supplied interfacing.
4. Operation outside the environmental specifications of the product.
5. Improper site preparation and maintenance.
6. Unauthorized modification or misuse.

Coherent assumes no responsibility for customer-supplied material.

The obligations of Coherent are limited to repairing or replacing, without charge, equipment which proves to be defective during the warranty period. Repaired or replaced parts are warranted for the duration of the original warranty period only. This warranty does not cover damage due to misuse, negligence or accidents, or damage due to installations, repairs or adjustments not specifically authorized by Coherent.

This warranty applies only to the original Buyer at the initial installation point in the country of purchase, unless otherwise specified in the sales contract. Warranty is transferable to another location or to another Buyer only by special agreement which will include additional inspection or installation at the new site.

THE WARRANTY SET FORTH ABOVE IS EXCLUSIVE IN LIEU OF ALL OTHER WARRANTY, WHETHER WRITTEN, ORAL OR IMPLIED, AND DOES NOT COVER INCIDENTAL OR CONSEQUENTIAL LOSS. COHERENT SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

PARTS LIST

Table D-1. Parts List

DESCRIPTION	PART NUMBER
EVOLUTION 15	
Chiller for 110 V	100-5377
Chiller for 220 V	100-9277
Diode Array Laser 40 W	714-5022
Mirror, HR 1053 nm, 0 Deg, fold mirror	703-5018
Mirror, HR1053/527 nm, 0 Deg, end mirror	704-5019
EVOLUTION 30	
Chiller for 110 V	100-9734
Chiller for 220 V	100-2036
Diode Array Laser 80 W	714-9358
Mirror, HR 1053 nm, 0 Deg, fold mirror	703-9792
Mirror, HR1053/527 nm, 0 Deg, end mirror	705-2010
COMMON FOR EVOLUTION 15/30	
Mirror, HR 1053 nm, 0 Deg, end mirror	703-5011
Mirror, HR 1053, 45 Deg, fold mirror	705-5229
Mirror, Dicroic, 45 Deg, fold mirror	705-2011
Mirror, HR 527 nm, 45 Deg, turning mirror	705-0791
Output Lens, AR 527 nm	701-1098
LBO assembly with crystal	100-2255

GLOSSARY

°C	Degrees centigrade or Celsius
°F	Degrees Fahrenheit
µ	Microns
µrad	Microradian(s)
µsec	Microsecond(s)
$1/e^2$	Beam diameter parameter
A	Amperes
AC	Alternating current
AGC	Automatic gain control
BPF	Band pass filter
CDRH	Center for Devices and Radiological Health
cm	Centimeter(s)
CW	Continuous wave
DC	Direct current
EMC	Electromagnetic compliance
GHz	Gigahertz
Hz	Hertz
IR	Infrared
kg	Kilogram(s)
kHz	Kilohertz
LED	Light emitting diode
LVD	Low voltage directive
m	Meter(s)
mA	Milliampere(s)
MHz	Megahertz
mm	Millimeter(s)
mrad	Milliradian(s)
msec	Millisecond(s)
mV	Millivolt(s)
mW	Milliwatt(s)
Nd:YLF	Neodymium doped yttrium Lithium Fluoride
nm	Nanometer(s)
OEM	Original equipment manufacturer
PZT	piezo-electric transducer

RF	Radio frequency
rms	Root mean square
Rx	Receive
TEM	Transverse electromagnetic (cross-sectional laser beam mode)
Tx	Transmit
VAC	Volts, alternating current
VDC	Volts, direct current
W	Watt(s)

INDEX

Evolution-15/30 Laser Operator's Manual

Part No. 1063004, Rev AA